EXPERIMENTAL TECHNIQUES IN HOLOGRAPHIC INTERFEROMETRY

Richard Allan Everett

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

& Van Houten (V168)

EXPERIMENTAL TECHNIQUES IN
HOLOGRAPHIC INTERFEROMETRY

by

Richard Allan Everett

Thesis Advisor: D.J. Collins

June 1973

Experimental Techniques In Holographic Interferometry

by

Richard Allan Everett
Lieutenant, United States Navy
B.S., Naval Postgraduate School, 1971

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
June 1973

ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

TABLE OF CONTENTS

I. <u>EXPERIMENTAL WORK ON FIBER OPTICS</u>

A. INTRODUCTION

Holographic interferometry is an invaluable and frequently used tool in modern flow field visualization. Numerous articles have reported on the application of holography to interferometry, among the first of which was presented by Heflinger, et al. [Ref. 1]. The history, the theory, and diverse applications of holography are presented in Collier [Ref. 2]. Holographic application to interferometry has been extensively investigated for pure gas flows [Ref. 3], for flows around transparent bodies [Ref. 4], and for flows around opaque bodies [Ref. 5].

The principles of holography have been known since 1947 when Gabor developed the principle as an improvement for electron microscopy [Ref. 2], but the current scientific applications awaited the development of a coherent visual radiation source. Previously, flow field visualization relied on interferometric techniques utilizing light sources of poor temporal coherence.

The specialized area of interferometric holography includes such techniques as real-time, time-averaging, stroboscopic, and time-lapse. They are discussed in Ref. 6. The time-lapse technique, also referred to as double exposure, is used for flow field visualization. This technique involves superimposing the phase and amplitude information of a flow condition upon that of a no-flow

[illegible]

condition. An improvement to time-lapse holography was achieved by the use of diffusing screens positioned in the scene beam. The idea was advanced by Heflinger [Ref. 1], while Gates further developed the concept [Ref. 7]. In normal side-band holography, each point on the object acts as a diffusely reflecting light source. Light reflected from all points on the object can mutually interfere with light from all other points. The total interference pattern produces a three-dimensional image. This three-dimensionality can be obtained in holographic interferograms of transparent objects by introducing a diffusing glass plate in the scene beam just prior to the test section.

Two varieties of time-lapse holography are the infinite fringe and the finite fringe methods. Infinite fringe patterns occur when the wave fronts of the separate exposures see exactly the same optical arrangement. Finite fringe patterns occur when a finite displacement is introduced in the optical arrangement between exposures. The fringe for the undisturbed region are parallel, equispaced lines which will be perpendicular to the direction of translation. These parallel, equispaced lines form a convenient scale for determining the fringe shift values in the disturbed region of flow.

The double exposure has the advantage of relaxing the tolerances of the optical equipment. Both flow and no-flow beams travel common optical paths which effectively eliminates the interference fringes from optical imperfections

of the experimental apparatus. This phenomenon is such that good quality holograms can be constructed with extremely rudimentary setups and optical components.

One final improvement in technique was required for the true versatility of holographic interferometry to emerge. Mechanical stability of the experimental components was required to achieve proper fringe interference patterns. The stability needed to be on an order of the wavelength of the light being used. The pulsed laser has eliminated stability problems during exposures by its ability to "freeze" the flow through exposure times in the tens of nanoseconds. Inherent in the pulsed laser is a loss of coherency length as compared to the continuous-wave laser (c.w. laser). Coherency lengths are strongly dependent on the number of modes that can oscillate simultaneously. For pulsed lasers, coherency lengths are normally on the order of tens of centimeters.

There is a need to relax the typical experimental arrangement to further expand the versatility of holographic interferometry. Data for flow field visualization must normally be collected from wind tunnel tests which only simulate real life. Freedom from the laboratory environment could be achieved by adapting fiber light guides to channel coherent light to and from real-life flows. Interferometric data could thus be collected on many interior flows or hazardous flows which do not lend themselves to standard experimental setups. Real-life flows such as inlet flows

or compressor flows could be investigated. To determine the feasibility of applying fiber optics in this fashion, a basic interferometric experiment was conducted using a fiber light guide to transmit a portion of the laser beam to the photographic emulsion.

B. EXPERIMENT

1. Equipment

The initial endeavor to achieve holograms using fiber optics was made with a 15 m.w. continuous wave helium-neon laser. Having found this inadequate, a Korad K-1 pulsed ruby laser with a Pockels cell Q-switching device was used in its place. The laser operates at a wavelength of 6943 Angstroms and has an effective exposure time of 20 nanoseconds. The fiber optics employed were 1/4-inch bundles, one being twelve inches in length and the other 24 inches. The c.w. laser was used for alignment of the pulsed laser beam through all the optical components. Also, the c.w. laser was used to establish the relative intensities of the scene and reference beams. Optical components consisted of several concave lenses, a beam splitter which was 20% reflective, front surface mirrors, and diffusing glasses of several different densities. A precision X-Y translating stage was used to achieve finite fringe lines. A schematic of the experimental arrangement is shown in Figure 1. Because the experiment was to be a double-exposure hologram, the quality of the optical

components was not of concern. An optical bench for isolating extraneous vibrations from the experiment was also deemed unnecessary due to the high speed exposures being used. The photographic emulsions used were AGFA-GEVAERT 10E75 holographic plates.

2. Michelson Interferometer

A Michelson interferometer [Refs. 2, 6, and 8] was constructed to make an initial start in determining the feasibility and the associated problems of holography employing fiber optics. One path length of the interferometer was replaced by a fiber light guide. [Fig. 2] The refractive index for the optic bundle was taken as 1.5 and an appropriate compensation was made in the optic path lengths. The interferometer is a test for temporal coherence of light. Temporal coherence for laser sources of light is extremely good and is the basic quality allowing for the development of the modern expansion of holography. When the paths are exactly matched, a well-defined circular interference pattern should be visible on the screen. If one path length is changed (ΔL) the fringe pattern becomes less distinct. The point at which the fringe could be considered no longer existent is a subjective quality and the value of $2\Delta L$ at this arbitrariliy accepted visibility of the fringe lines defines the temporal coherence length of the laser. Pulsed lasers have coherence lengths on the order of 10 to 20 cm.

3. Holographic Arrangement

The holographic arrangement is illustrated in Figure 1. The pulsed laser was mounted on an optical rail along one side fo the work table. In its path a removable front surface mirror was positioned which directed the alignment laser along the identical path as the pulsed laser. The high intensity pulse was spread by a concave lens to prevent the high intensity beam from scoring either the beam splitter or the fiber optics. The beam splitter was 20% reflective allowing the greater amount of energy to enter the fiber optics. It was necessary to direct a high percentage of the energy into the fibers for there is a 43% internal optical loss associated with the 24 inch length. Also, the divergence of the beam leaving the fibers is sufficient to cause a rapid loss in beam intensity as the free-air path length of the beam is increased. The reflected beam was used as the reference beam. It was directed to a front surface mirror and through two concave lenses to the photographic surface. The other portion of the beam entered the fiber bundle after passing through the beam splitter and was then directed to the photographic plate. Both beams had a 30% incidence angle to the normal of the photographic plate. A precision X-Y translation stage was used in the scene beam. It was initially used to translate the fiber ends and later to translate a diffusing plate placed in the scene beam.

Alignment and the relative intensities of the scene and reference beams were achieved with the c.w. laser. Alignment was achieved in the following manner. At two points 0.5 meters apart along the optical, rail blackened photographic papers were positioned. These were burned with the pulsed laser using a 1.5 mm. aperture. Pin holes were made in the center of each spot. A removable mirror was placed on the rail which reflected the c.w. laser beam through the two pin holes. This beam was a visual equivalent of the invisible pulsed laser beam and could be readily aimed through the optical components. Each beam was centered on a target grid set in the photographic plate holder.

The loss of intensity through the fiber optics was not a controllable factor and as such, all adjustments for the relative intensity of the two beams were made to the reference beam. Two concave lenses closely spaced gave the needed control of the divergence of this beam. White sheets of paper were held in front of each beam and a visual estimation of the intensities was made. It was attempted to have the reference beam from two to three times as intense as the scene beam.

The equivalent free-air path lengths for both beams was approximately 190 cm. The free air portion of the scene beam, that portion from the exit of the fiber optics to the photographic plate, was determined by two factors;

having the fibers far enough away to achieve maximum coverage of the photographic plate, and not being so far as to seriously diminish the intensity of the beam.

4. <u>Testing Procedure</u>

To initiate testing, all alignment devices were removed and a 2.5 mm. aperture was placed in the transverse mode selector. It proved prudent to make an additional test for correct alignment and relative intensities before proceeding with the actual experiment. This was accomplished by making two initial exposures, allowing only one beam at a time to expose each of two different plates. After developing these plates, a more reliable visual comparison could be made of the two beam intensities. This also gave assurance that both beams were sufficiently centered on the photographic plate.

To prove the feasibility of holographic interferometry employing fiber optics, an initial step was to achieve finite fringe lines of a no-flow condition. Since the fibers consist of a large number of independent light sources, each one emanating from the end of each individual fiber, it was felt at first that this property of the light guide would obviate the need for a diffusing plate in the scene beam as is customarily used. As such, the fiber bundle was attached to the X-Y translation stage. Between exposures the stage was translated 0.003 inches horizontally to produce vertical fringe lines. Additionally, the experiment was performed

using a diffusing plate translated in the same manner, in place of translation of the fiber optics.

C. RESULTS

1. Michelson Interferometer

The Michelson interferometric experiment produced positive results. A fringe pattern was observed on the screen from the interferometer employing the fiber light guide. The temporal coherence was preserved through the fiber optics. It became evident that the experiment was highly sensitive to vibration. This portion of work was accomplished on a vibration isolating optical bench. When the experiment was initially performed without fiber optics, the fringe pattern would waver whenever slight shocks were induced in the concrete floor of the test room. Once the fibers were positioned, the sensitivity to vibration was greatly heightened. The fringe pattern was observed only after extensive and minute adjustments were made to the optical components. The fringe pattern was seen for but an instant. Because of the difficulty of stabilizing the optical arrangement, no further investigation was made to determine whether there was a degradation of coherency length by the fiber optics. The apparent increased sensitivity to vibration of the fringe formation necessitated using high-speed exposures achieved with a pulsed laser for all further work.

2. Holographic Experiment

The first phase in the experiment sought to ascertain the need for a diffusing plate. In view of the large number of individual fibers contained in the light guide, would each fiber act as an individual light source and produce a similar effect to that of a diffusing plate? Initial holograms were made of a transparent phase object, a rhombohedral plastic form, as well as finite fringe lines. The technique proved unsuccessful. Finite fringe lines were not produced. However, a hologram of the phase object was achieved. It was of poor quality and contained only a picture of the light emitted by the fibers and several high-intensity reflections of light from the inner walls of the rhombohedron. The appearance was exactly that of previous holograms attempted where a diffusing plate was not incorporated.

Further testing was limited to achieving a finite fringe pattern using the diffusing plate attached to the translating stage. Vertical fringe lines of a no-flow condition were achieved. The fringe lines were clearly visible, but were confined to only a portion of the photographic plate.

During the alignment portion of the experiment, it was noted that the uniformity of the beam from the fiber optics was greatly influenced by the positioning of the incidence beam. The most uniform pattern was achieved by an incident beam covering approximately one third of the

area of the fiber ends. This result was enhanced if the beam was directed off center. Minute changes in its position on the fiber ends greatly influenced the quality and focus of the emitting beam. Since the pulsed beam is unobserved, no positive control of the beam from the fibers was assured. It would be reasonable to suspect this uncertainty for the number of failures and the eventual poor quality of the holograms achieved.

II. THEORETICAL INVESTIGATION OF LIMITED FIELDS OF VIEW IN HOLOGRAPHIC INTERFEROMETRY

A. INTRODUCTION

An attempt was made to further investigate the problem of data reduction for supersonic flows containing opaque bodies. An initial effort toward this was presented by Jagota and Collins [Ref. 5]. Known values of density along various lines of sight were obtained from AGARD [Ref. 9] for a specific cross section in the flow about a cone. To diminish the effect of the presence of the cone in the flow, a fictitious constant density distribution equal in value to the density at the cone surface was added. The new density field, which now covered the entire test section area, was used to calculate a fringe number array that would have resulted from such a density distribution. These data were then reinverted to obtain a density distribution which was compared to the original density. Reference 8 contains the computer program used for the data reduction.

Further research into flow around opaque bodies has been facilitated by the development of an alternate computer program using a Fourier transform method in place of the Fourier expansion used in Ref. 8 to solve the pertinent equations. Van Houten discussed this method in Ref. 10. The main advantages of the program are in the computational time required and the numerous options available to the user.

Computational times on the order of two minutes made the program by Van Houten ideally suited for exploring different schemes to calculate the density field around an opaque object.

B. PROCEDURE

Because one would normally be starting with experimentally observed fringe data, manipulation of this information was chosen as a starting point instead of the density field change used in Ref. 5. A fictitious density distribution was formulated corresponding to Fig. 8 of Ref. 10. The relative refractive index function was given by:

$$
\begin{aligned}
f(X,Y) &= (1 - Y^2)\, e^{-2X^2} && R \leq 1.5 \\
&= 0 && R > 1.5 \\
R &= X^2 + Y^2
\end{aligned}
\qquad \text{eq. (1)}
$$

The computer program used this input to calculate a refractive index field over a 4 in. by 4 in. cross-sectional area. The field was calculated at 101 equispaced points on both the X and Y axes. Mode 1 of the program starts with the relative refractive index function, calculates an initial refractive index field at selected points from this, computes the fringe shift that would be observed from the field, and recalculates a new refractive index field from the fringe shift information. These calculations were used as standards against which other flow fields were to be compared.

Two experimental phases were studied; Van Houten's Fig. 8 was centered within the test field, and the same figure was translated 0.25 in. along both axes. The KSYM argument of the computer program, which is a measure of symmetry of the field about the origin, changed between cases. The translation destroyed the symmetry found along both axes in the original figure.

Mode III of the program uses fringe information supplied as data, and from it calculates a refractive index field. To simulate the presence of an opaque body immersed in the flow, fringe information obtained from Mode I was blocked over a portion of the field. The blocked portion was the center portion of the flow field. This portion of the fringe data blocked by the presumed body was restored using two numeric schemes. The reconstructed fringe shift information was used to recalculate the refractive index field. This allowed for a direct comparison between density distributions of the free flow with that of a flow around the opaque body.

The program from Ref. 10 was modified for this use and is presented in Appendix A. Two schemes were used for reconstructing the lost fringe information. The first method used a U. S. Naval Postgraduate School Computer Library subroutine titled INTRPL. This was incorporated in a subprogram [Appendix B] that read in the entire fringe shift information and automatically destroyed the middle quarter of the data. INTRPL used the remaining field to

recalculate the missing portion. The second scheme [Appendix B] filled the same missing information with a linear interpolation. The two newly constructed fringe number arrays were reinserted in the main computer program under Mode III and the resulting refractive index fields were obtained.

C. RESULTS

Six separate computer runs were made, the first three dealing with the function centered on the X- and Y-axes, and the last three dealing with the displaced function. Each group of three runs commenced with a given refractive index function from which was calculated the refractive index field at selected grid points using the Mode 1 operation. All subsequent runs were done under Mode 3. The second run of each group used the fringe shift array as modified by the INTRPL subprogram. The third run used the same information as modified by the linear interpolation subprogram. A diagram of the calculating procedure is given in Figure 3.

Contour plots of all refractive index fields were used to compare results for the different cases. Contour lines were produced at 0.1 intervals from the maximum function value of 1.0 to the minimum value. Comparisons among the contour plots were made using two different criteria; errors of the test case values from the values of the standard case in percent of the maximum value of the function, and the number of calculation grid points between

equal contour levels of each graph. Comparisons were terminated at the boundary of the simulated body. The body consisted of a circular region of a 0.5 in. radius located at the center of the cross-sectional area.

1. Centered Function

Figure 4 presents the refractive index field calculated by Mode 1 using the density function given in Equation 1. This is the standard of comparison for the other centered cases. In Fig. 5, the center portion of the fringe array has been removed and replaced by the subroutine INTRPL. In Fig. 6, the center portion of the function has been removed and replaced by a linear interpolation.

The greatest error encountered in comparing the standard, Fig. 4, with Fig. 5 was at the surface of the body. This error was on the order of 8%. Errors around most of the body were approximately 5%. Elsewhere in the flow, the maximum error observed was 2.5%. Generally, the lower-valued contour levels away from the body were very closely matched.

A comparison of Fig. 4 and Fig. 6 produced greater errors. The contour lines developed sinusoidal-like oscillations over the entire flow field. For comparing these irregular contour levels a mean value between peaks in the oscillation was estimated and compared with the standard case. Again, the greatest error was found at the body surface. There was a 10% error in the positive Y-direction

that diminished rapidly around the rest of the body. Errors away from the body were negligible along the Y-axis, but were 6% along the X-axis.

2. Displaced Function

Figure 7, calculated in the same manner as Fig. 3, is the standard of comparison for the displaced cases. In Fig. 8 and Fig. 9, the center portions of the fringe array were, as before with the centered functions, replaced by INTRPL and by the linear interpolation, respectively.

A comparison of Fig. 7 with Fig. 8 showed slightly increasing errors over those of the centered cases. The greatest error occurred again where contour levels intersected the body. Errors in this region were from 7% to 12%, the higher error being associated with the higher contour levels. Elsewhere, there was good agreement between the two figures with the maximum error being on the order of 4%.

Figure 9 again produced sinusoidal-like oscillations. Using the same procedure discussed for Fig. 6, the maximum error was found to be about 5%. Again, as the contour lines neared the body, accuracy was lost. Errors had improved slightly in this region over the last comparison and were from 7% to 10%.

3. General Trends

Errors for the centered functions were found to be concentrated along the X-axis. Errors for the displaced functions were generally found in quadrant III. Flow fields

for both functions showed little error along the Y-axis. It should be noted that the Y-axis contained a discontinuity and a region of negative values.

The second method used to compare flows determined the number of grid points between like values of contrasted flows. The accuracy in the general location of contours from figure to figure was considered good. Contours locations differed by no more than two grid points.

III. CONCLUSIONS AND RECOMMENDATIONS

It has been demonstrated that fiber light guides can be applied to holographic interferometry. The experiment was rudimentary and requires refinement. The problems encountered in the course of the experiment involved accurate alignment of the pulsed laser beam and attenuation of energy associated with the fiber optics.

If more realistic experiments are to be conducted, longer fibers will possibly have to be used. Transmission losses of the order of 65% are associated with six-foot lengths of fibers. A means of coping with this high magnitude loss is needed.

The incomplete fringe information associated with the limited fields of view caused by an opaque body positioned in a flow field was tested using two methods of calculating data values for the blocked portion of the fringe array. Both methods provided fair estimates of the flows in the region near the surface of the body, but there was a general degradation of flow information over the entire flow region producing errors on the order of 5% to 10%.

In using the Fourier transformation method for fringe conversion given in Ref. 10, there is a degradation to the flow field due to the finite spacing of the grid points. This effect has not fully been investigated. Errors associated with the two schemes for creating fringe data

for blocked portions of the flow can compound the inherent errors of the basic program.

Further endeavors could be made in determining the effect on the investigation caused by differing the percentage of view that is blocked. The program could be run using a finer grid pattern or a greater number of views. These factors could all have an effect on flow errors.

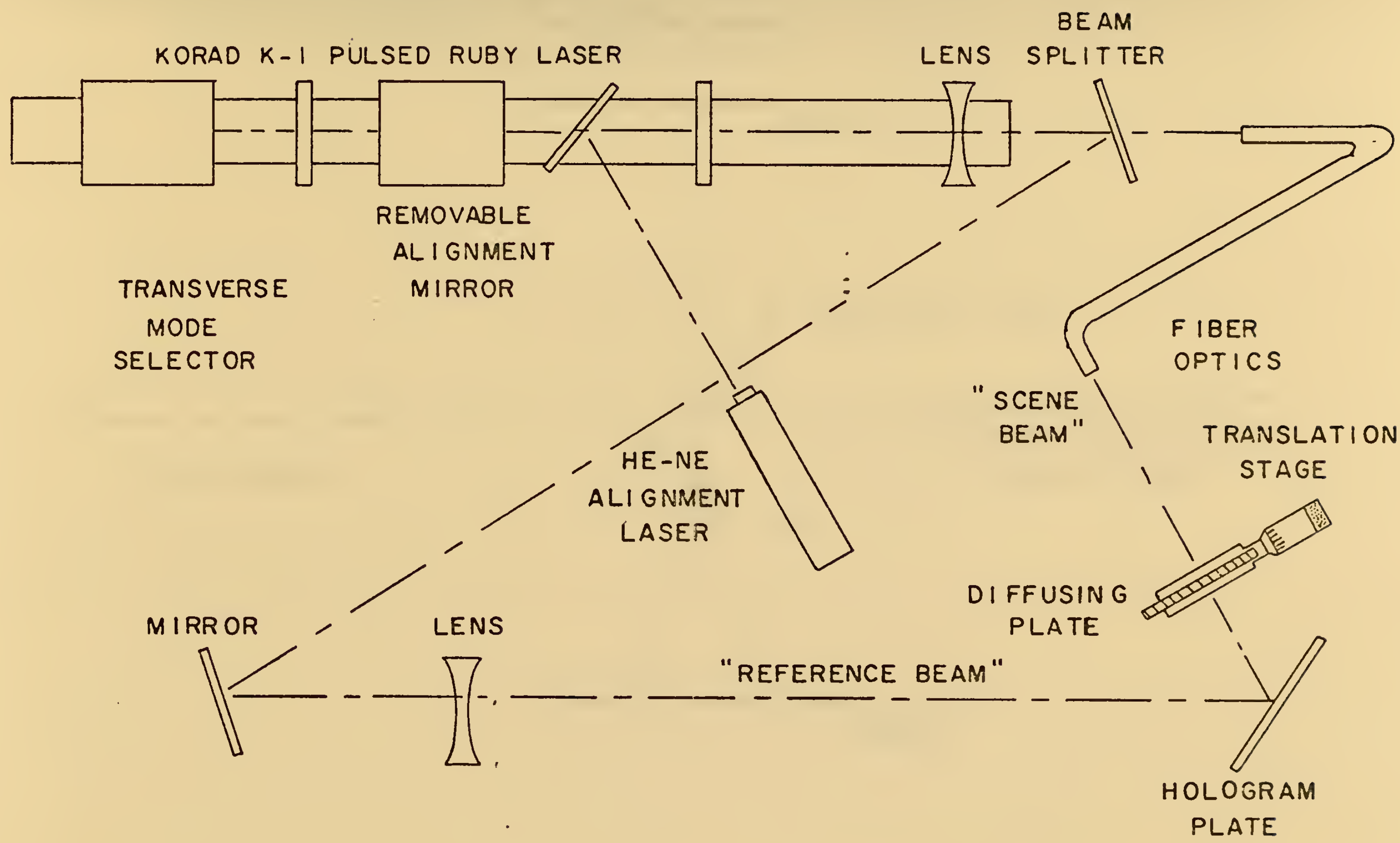

FIGURE I. SCHEMATIC DRAWING OF THE HOLOGRAPHIC ARRANGEMENT

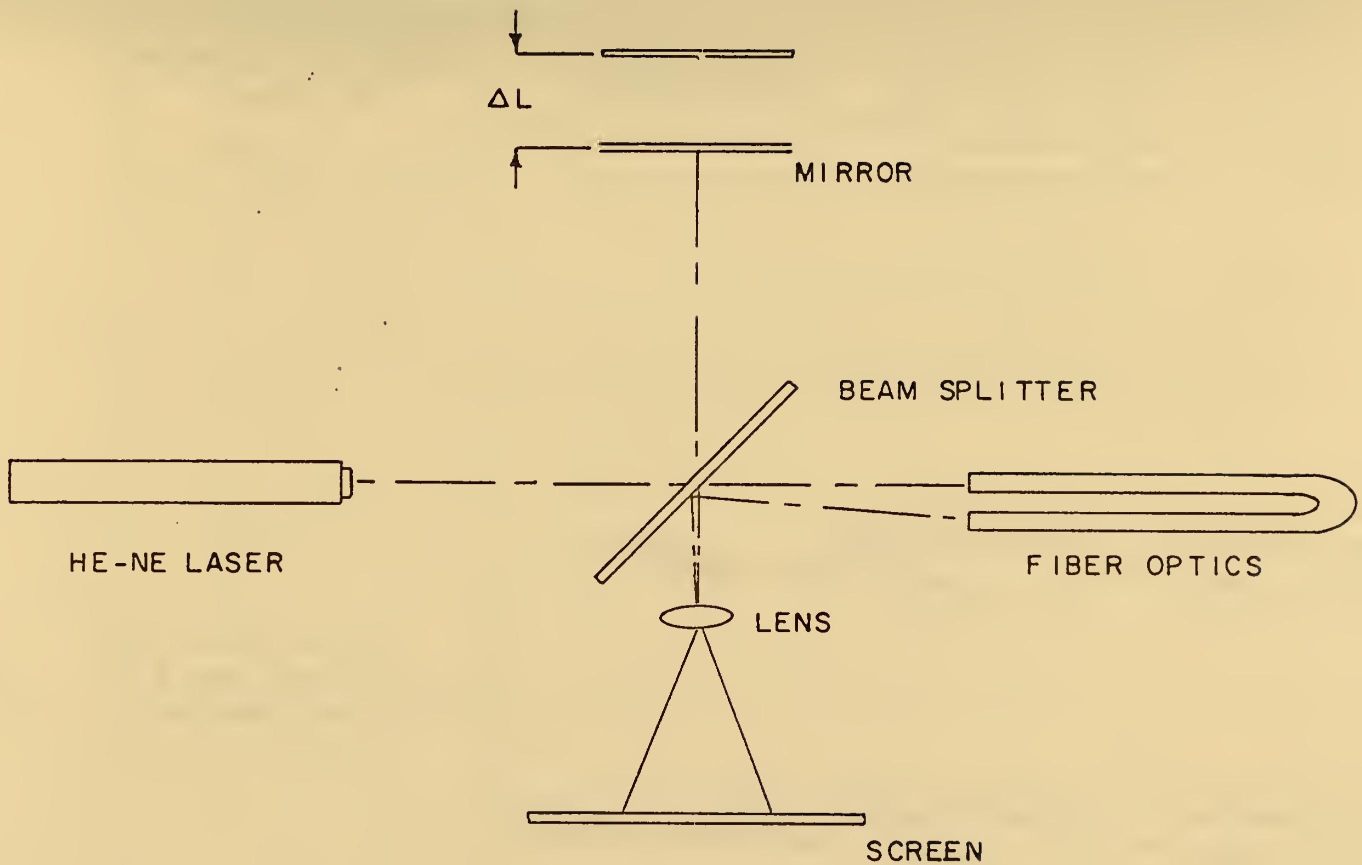

FIGURE 2. MICHELSON INTERFEROMETER WITH FIBER OPTICS

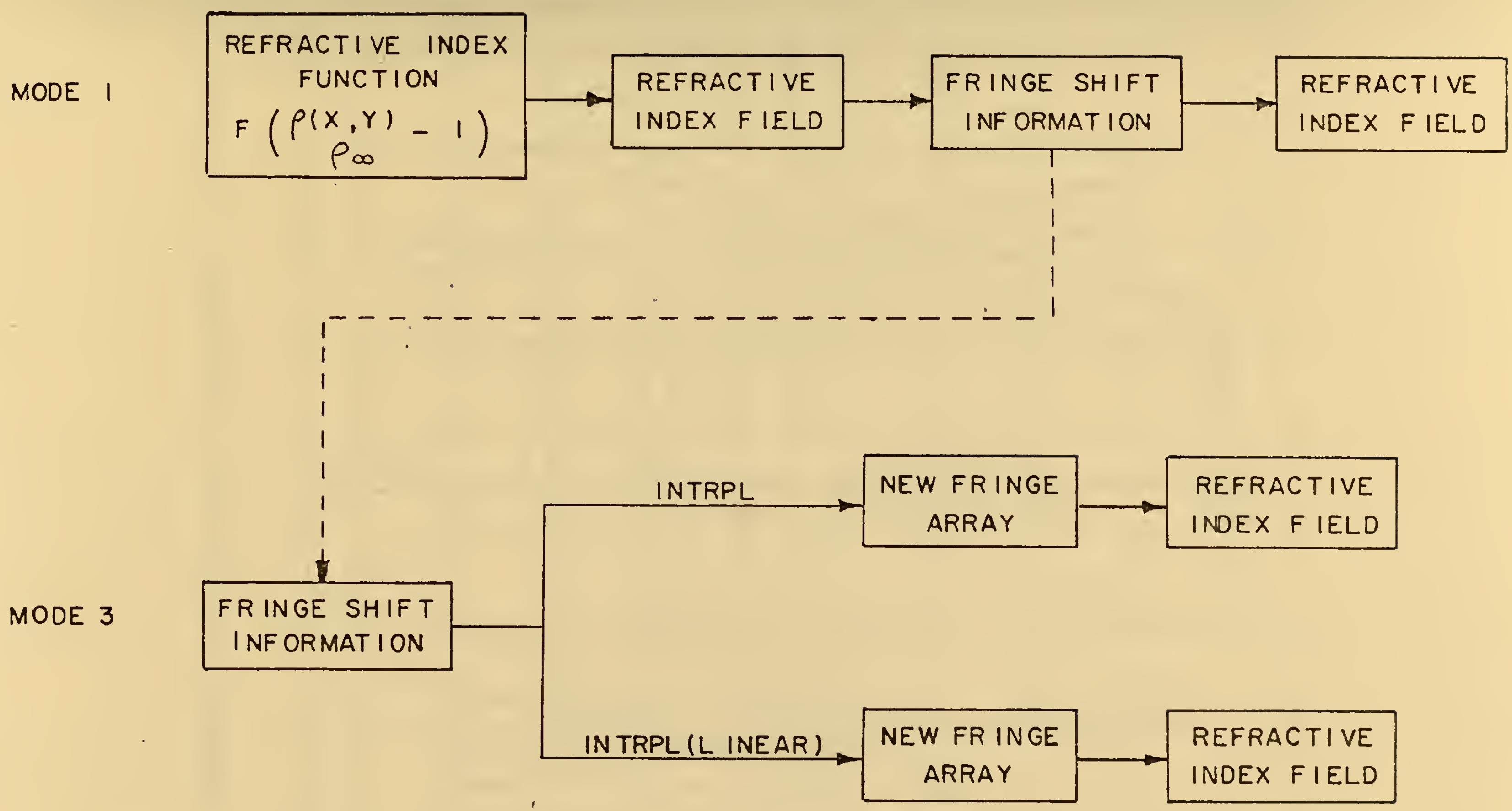

FIGURE 3. CALCULATION FLOW DIAGRAM

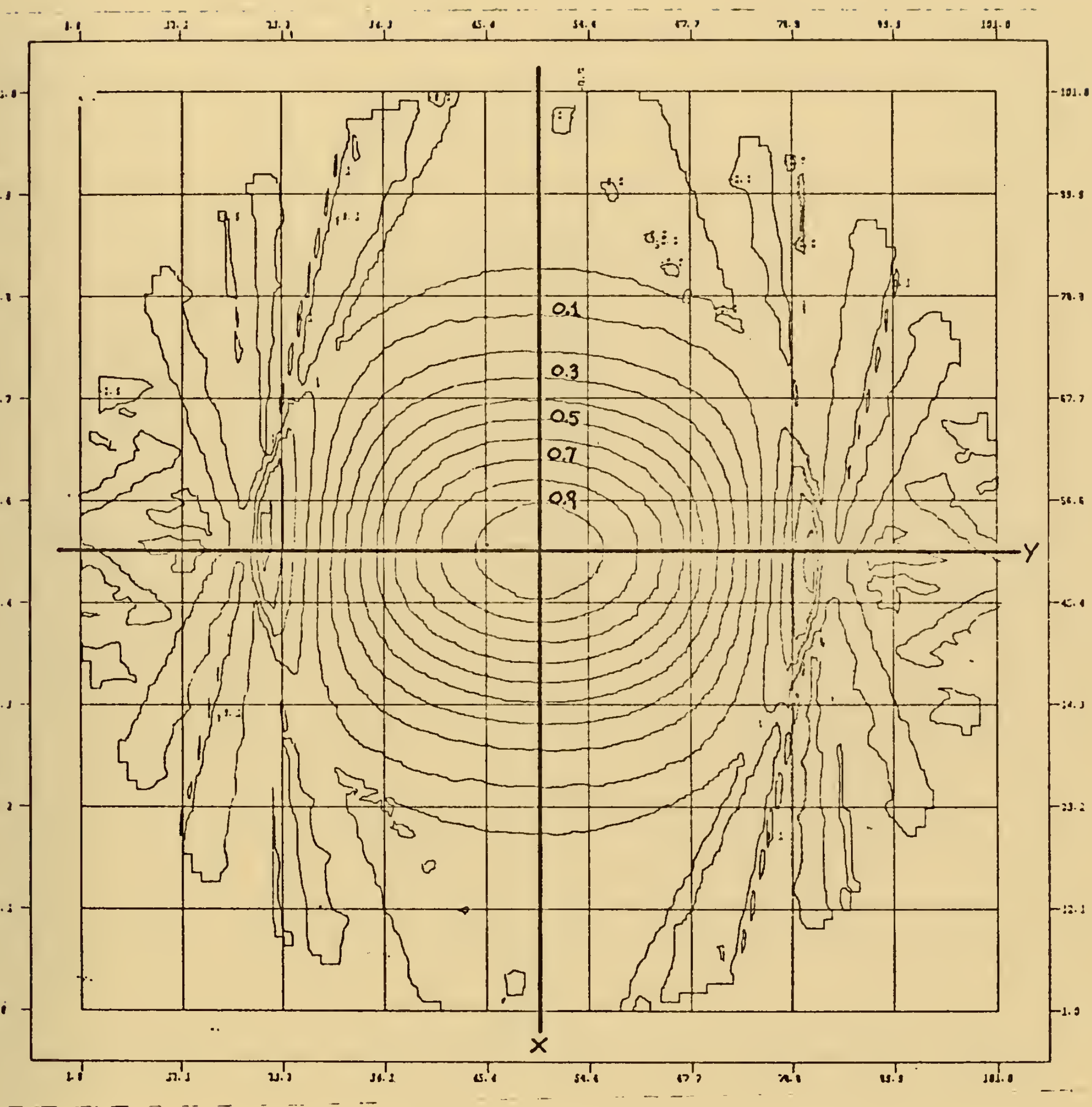

Figure 4. Standard Case for the Centered Function

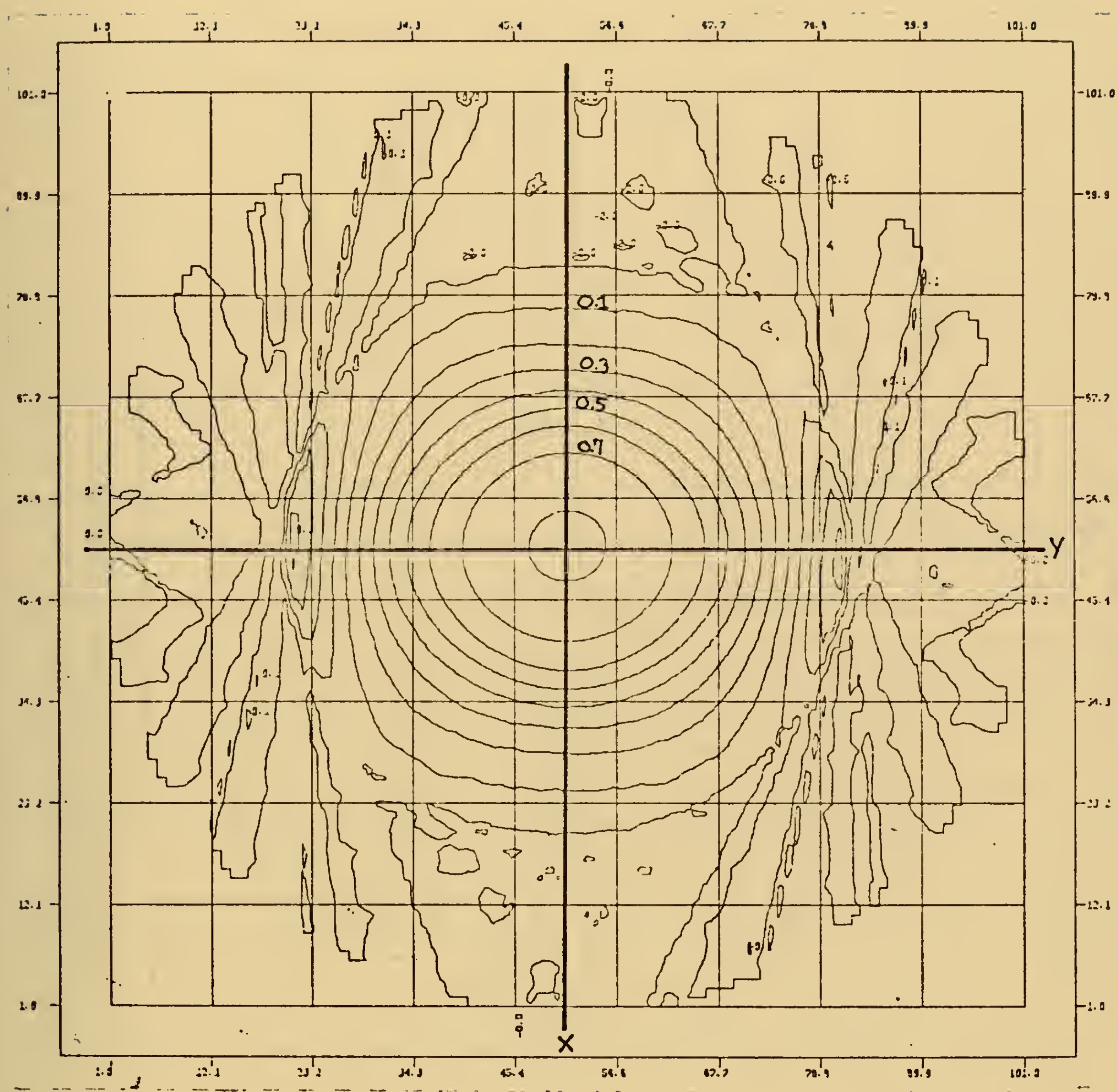

Figure 5. Centered Function Modified by INTRPL

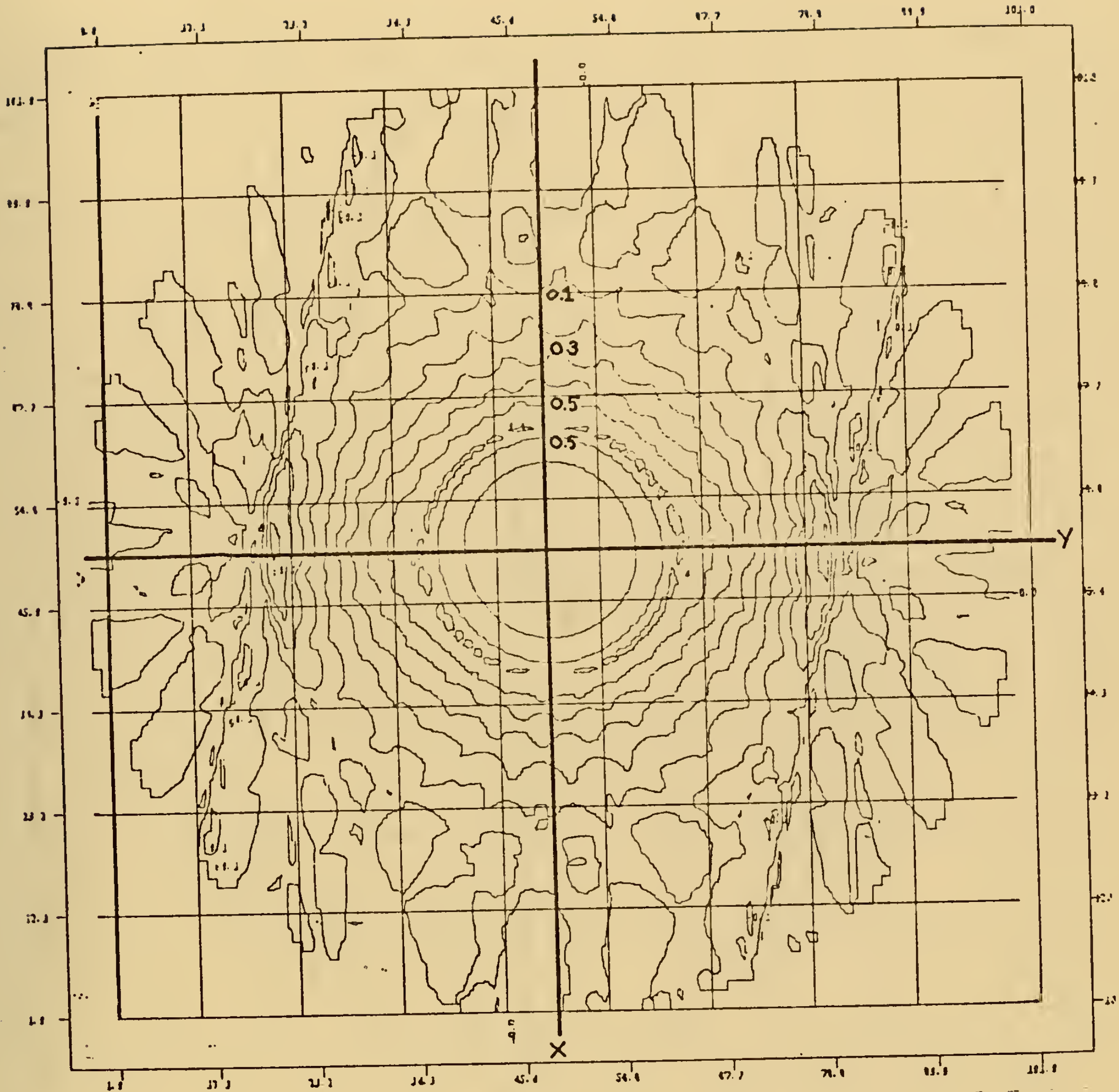

Figure 6. Centered Function Modified by INTRPL (LINEAR)

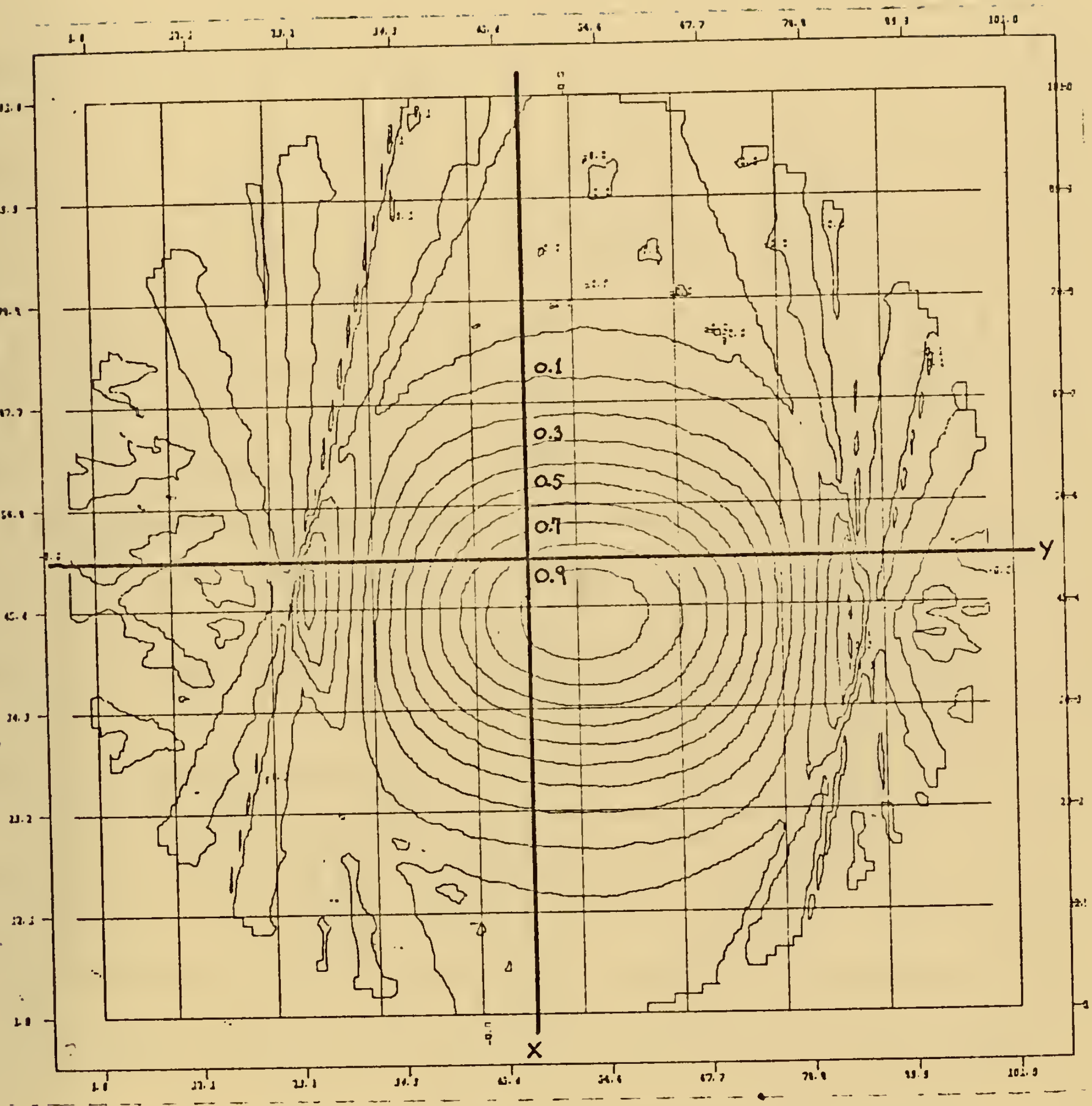

Figure 7. Standard Case for the Displaced Function

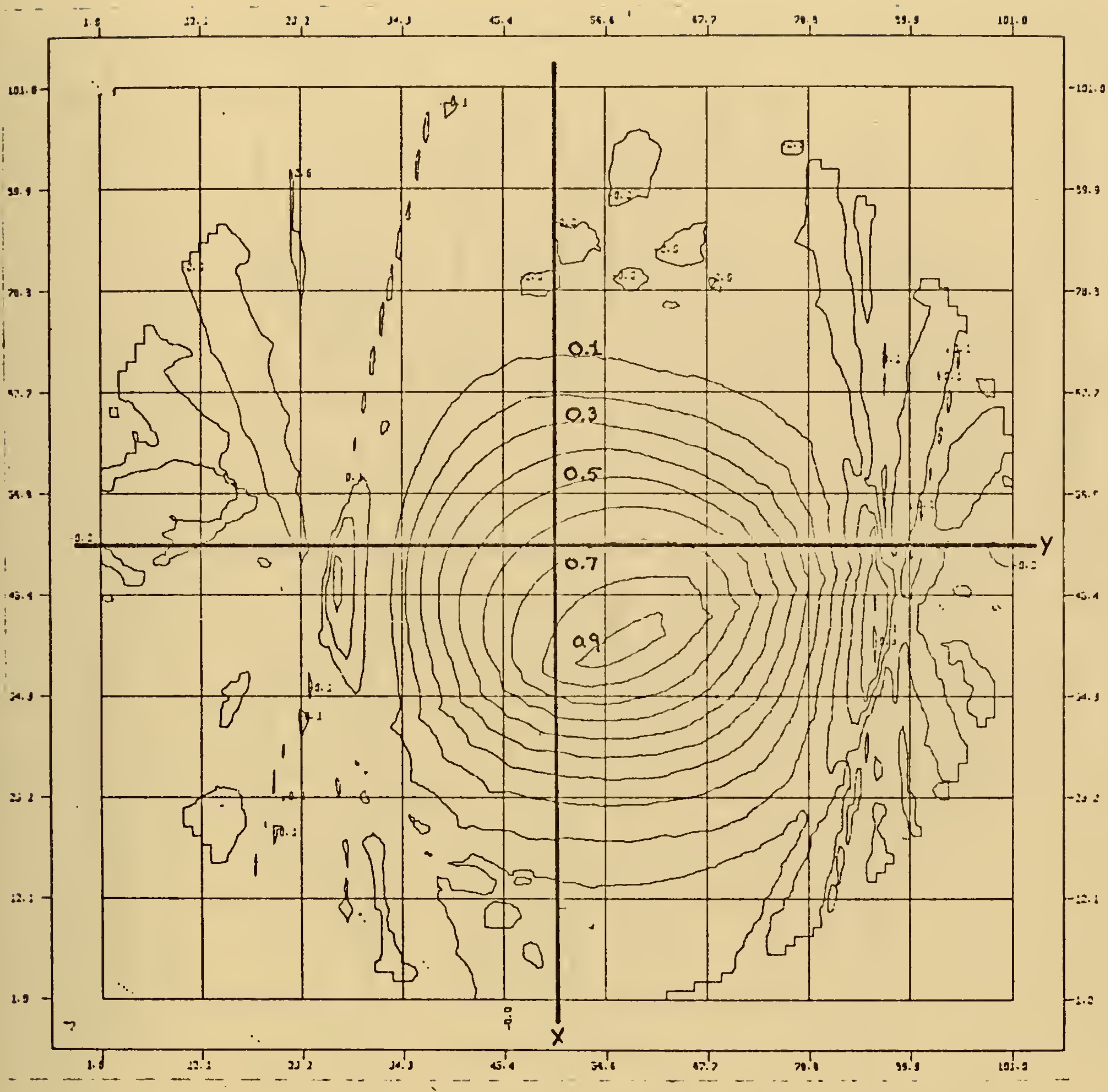

Figure 8. Displaced Function Modified by INTRPL

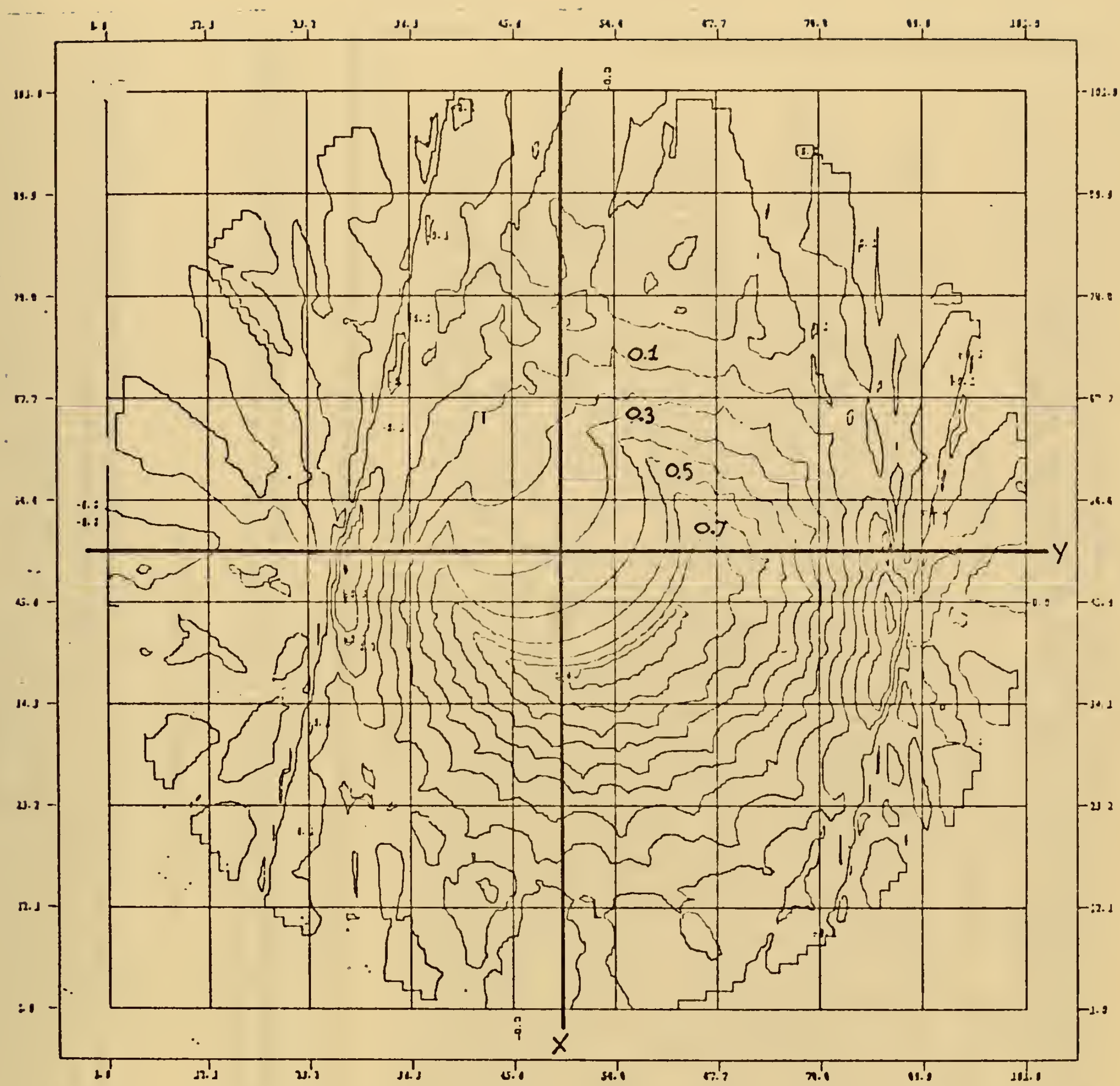

Figure 9. Displaced Function Modified by INTRPL (LINEAR)

APPENDIX A

```
*****************************************************************************
*****************************************************************************

                          MAIN COMPUTER PROGRAM

*****************************************************************************
*****************************************************************************

*************************************************************************
*                                                                       *
*                        INTEGRAL INVERSION                             *
*                                                                       *
*  REFERENCE, THESIS BY P. E. VAN HOUTEN 'THE APPLICATION OF           *
*  HOLOGRAPHIC INTERFEROMETRY TO THE DETERMINATION OF DISCON-          *
*  TINUOUS THREE-DIMENSIONAL DENSITY FIELDS' 14 DEC 72                 *
*       THE PROGRAM CONSIDERS A CIRCULAR REGION OF UNKNOWN             *
*  REFRACTIVE INDEX FOR WHICH THE TOTAL PHASE SHIFT(PATH LENGTH        *
*  DIFFERENCE) IS KNOWN FOR NUMEROUS RAYS AT REGULAR INTERVALS         *
*  FOR A GIVEN VIEWING ANGLE. THE PROGRAM REQUIRES NUMEROUS            *
*  VIEWS AT REGULARLY SPACED INTERVALS AND A TOTAL ANGULAR             *
*  COVERAGE OF 180 DEGREES(ASYMMETRIC). THE NECESSARY ANGULAR          *
*  COVERAGE IS REDUCED BY THE NUMBER OF DEGREES OF SYMMETRY.           *
*  BY THE USE OF TWO DIMENSIONAL FOURIER TRANSFORM TECHNIQUES          *
*  IT CAN BE SHOWN THAT  FOR A GIVEN POINT(XO,YO) WITHIN THE           *
*  CIRCULAR REGION, THE DENSITY F(XO,YO) CAN BE EXPRESSED IN           *
*  TERMS OF THE PHASE SHIFT INFORMATION G(RO,THETA).                   *
*       IN ORDER TO SAVE COMPUTATION TIME, THE VALUE OF THE            *
*  INSIDE INTEGRATION IS COMPUTED AT EACH RAY POSITION FOR EACH        *
*  VIEWING ANGLE. FOR A GIVEN POINT(XO,YO), THE VALUE OF THE           *
*  INSIDE INTEGRAL IS DETERMINED BY AVERAGING OVER A FINITE            *
*  PORTION OF A CUBIC POLYNOMIAL FITTED TO THE FOUR CLOSEST            *
*  VALUES OF THE INSIDE INTEGRAL.  THE INTEGRATION OVER THETA          *
*  USES THE TRAPEZOIDAL RULE.  THE INTEGRATION OVER RHO USES           *
*  COTES SIXTH ORDER QUADATURE FORMULA                                 *
*                                                                       *
*     MEANING OF SYMBOLS USED IN THE PROGRAM                           *
*                                                                       *
*  IT(12)  TITLE USED FOR OUTPUT.  FIRST 48 CHARACTERS ON FIRST        *
*          DATA CARD, FIRST 16 CHARACTERS ON NEXT DATA CARD            *
*  RHOINF-DENSITY OUTSIDE REGION CF INTEREST IN MG/CC.                 *
*  XLAMDA-WAVELENGTH OF MONOCHROMATIC,COHERENT LIGHT SOURCE IN         *
```

```
*  MICRONS.                                                              *
*  RHOINF AND XLAMDA ON THIRD DATA CARD IN (2F10.5) FORMAT               *
*  MODE      MODE=1  REFRACTIVE INDEX SUPPLIED THROUGH SUBROUTINE        *
*                    'INPUT'. THE PROGRAM GENERATES FRINGE DATA          *
*                    AND RECOMPUTES THE REFRACTIVE INDEX FROM            *
*                    THE GENERATED FRINGE DATA.                          *
*            MODE=2  REFRACTIVE INDEX SUPPLIED AT GRID PCINTS            *
*                    BY INPUT DATA. PROGRAM PROCEEDS AS IN MODE 1        *
*            MODE=3 FRINGE DATA SUPPLIED, PROGRAM GENERATES              *
*                   DENSITY FIELD.                                       *
*            MODE=4  SAME AS MODE=3 EXCEPT FRINGE DATA IS RECOM-         *
*                    PUTED AS PER MODE =2.                               *
*  NP   NUMBER OF EQUALLY SPACED DATA POINTS                             *
*  NT   NUMBER OF VIEWS SUPPLIED                                         *
*  KSYM   SYMMETRY OF FIELD  0-4 AXIS OF  SYMMETRY                       *
*                            4 -98   DATA REPEATS EVERY KSYM             *
*                                    DEGREES.                            *
*                            99 AXISYMETRIC FIELD                        *
*  RMAX  RADIUS OF CIRCULAR REGION  IN CENTIMETERS                       *
*  FILTER = (0.-1.) DETERMINES SPAN OVER WHICH AVERAGING OCCURS          *
*  THE ABOVE INFORMATION ON THE FOURTH DATA CARD(4I10,2F10.5).           *
*  X(I)    VECTOR OF GRID POINTS ALONG THETA = 0 DEGREES                 *
*          X(1)=-RMAX     X(NP)=+RMAX                                    *
*  Y(J)    VECTOR OF GRID POINTS ALONG THETA=90 DEGREES                  *
*          Y(1)=-RMAX   Y(NP)=+RMAX                                      *
*  A(I,J)   DENSITY OR REFRACTIVE INDEX AT THE POINT X(I),Y(J).          *
*  RB(I) VECTOR OF POINTS ON THE HCLOGRAPHIC PLATE RB(1)=-2 RMAX         *
*  RB(2 NP)=2 RMAX.                                                      *
*  DR   SPACING OF GRID,SPACING OF RAYS.  DR=2*RMAX/(NP-1)               *
*  TH(K)   VECTOR OF VIEWING ANGLES  IN DEGREES                          *
*  B(I,K)    FRINGE SHIFT INFORMATION AT THE POINT(RB(I),TH(K)).         *
*  B(I,K) IS COPIED INTO BB(I,K). THE VALUE OF THE INSIDE                *
*  INTEGRATION IS THEN STORED IN B(I,K).                                 *
*  DASYM(K) SYMMETRY OF DATA(B(I,K). 0 NC SYMETRY                        *
*                                    1 DATA SYMETRIC ABOUT RB=0.         *
*  IF DASYM = 1.0 ONLY (NP+1)/2 DATA POINTS SHOULD BE FURNISHED.         *
*  BD(L) IS A WORK VECTOR USED BY THE PROGRAM.                           *
*  FOR MODE=1 OR  MODE=2 THE FIFTH DATA CARC IS THE VECTOR               *
*  TH(K) IN (8F10.5) FORMAT                                              *
*  FCR MODE 2 OPERATION THE REFRACTIVE INDEX FOLLOWS IN 8F10.5           *
*  FORMAT.                                                               *
*  FOR MODE=3 AND MODE=4 OPERATION, THE FIFTH DATA CARD IS               *
*  TH(1) AND DASYM(1) IN (2F10.5) FORMAT.  THIS IS FOLLOWED              *
*  BY THE FRINGE INFORMATION FOR THAT VIEW (B(I,1) ETC UNTIL             *
*  ALL VIEWS AND FRINGE SHIFT HAS BEEN SUPPLIED                          *
*  IF AXIS OF SYMMETRY EXISTS,THETA=0. MUST CORRESPOND TO ONE OF         *
*  THE AXIS OF SYMMETRY.                                                 *
*                                                                        *
```

```
      *******************************************************************
      REAL*8 IT(12),LAB,ITSUB(12)/'REFRACTIVE INCEXDENSITY IN MG/CC    T
     1HETA=  0DEG     THETA= 90DEG     THETA= 45DEG     THETA=-45DEG'/
      REAL*8 ITT(12)
      DIMENSION CL(18)
      DIMENSION X(101),Y(101),A(101,101),B(101,20),BD(811),TH(36),
     1BB(301,20),RB(301),DASYM(20),SS(36),CC(36)
      LOGICAL*1 LTG(3)
      F1(AA,BD,CC,RR)=CC+RR*(BD+RR*(AA))
      DATA NL,IW,IH/18,9,9/
      DATA C1,C2,C3,C4/.2292857,1.54285,.192857,1.94285/,LAB/'        '/
      DATA NMAP/2/
  109 FORMAT('0','NMAP=',I3)
  100 FORMAT (4I10,2F10.5)
  101 FORMAT('0',T20,'   MODE      NUM PTS   NUM VIEWS   KSYM    RADIUS
     1GRID SPACING  FILTER')
  102 FORMAT('0',T17,4I10,3F10.5)
  103 FORMAT(8F10.5)
  104 FORMAT('0',T7,20F6.1//)
  105 FORMAT('0',F5.2,20F6.2)
  106 FORMAT('0',//)
  107 FORMAT('0',T9,'MODE 1',T26,'MODE 3',T45,'VALUE'/,T9,'GIVEN    COMP
     1    DENSITY',T47,'OF'/,'RADIUS  REFRAC   REFRAC  FIELD     FRINGE
     2  INSIDE'/,'  CM    INDEX    INDEX   MG/CC     SHIFT    INTEGRAL'
     3//)
  108 FORMAT('0',T20,'RHCINF =',F7.5,' MG/CC  LAMDA=',F7.5,' MICRONS')
  110 FORMAT('1',T7,21F6.2//)
  111 FORMAT('0',F5.2,1X,21F6.2)
  112 FORMAT(6A8)
  113 FORMAT(' ',T40,'Y AXIS(THETA=90 DEGREES) VERTICAL'/,T40,
     1'X AXIS(THETA = 0 DEGREES) HORIZONTAL'//)
  114 FORMAT('0',T40,'DENSITY FIELD IN MG/CC FCLLCWS')
  115 FORMAT('0',T40,'INDEX OF REFRACTION FOLLOWS')
  116 FORMAT('1','THE EXPANDED FRINGE SHIFT INFORMATION IS AS FOLLOWS'/)
  117 FORMAT('1','THE VALUE OF THE INSIDE INTEGRATION IS AS FOLLOWS'//)
  118 FORMAT(10F7.4)
      DO 75 KXX=1,6
      NMAP=NMAP+1
      DO 120 I=2,19
      CL(1)=-0.8
      K=I-1
  120 CL(I)=CL(1)+K*0.10
      DO 121 I=1,3
      LTG(I)=.TRUE.
  121 CONTINUE
      READ(5,112) (IT(I),I=1,12)
      READ(5,112)(ITT(I),I=1,12)
      READ(5,103) RHOINF,XLAMD
```

```
      READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
      WRITE(6,106)
      WRITE(6,109) NMAP
      WRITE(6,112)(ITT(I),I=1,12)
      WRITE(6,108) RHOINF,XLAMD
      FNP=FLOAT(NP)
      DR=2.*RMAX/(FNP-1)
      WRITE(6,101)
      WRITE(6,102) MODE,NP,NT,KSYM,RMAX,DR,FILTER
      N=(NP+1)/2
      NPL=(NP-1)/2
      NPP=2*NP-1
      MAX=NP+NPL
      RM2=RMAX**2
      NP5=3*NP-2
      FNP5=FLOAT(NP5)
      NPM1=NP-1
      FT2=FILTER*FILTER

*****ZERO MATRICES AND SET GRID *************************************

      DO 2 I=1,NP
      DO 1 J=1,NP
    1 A(I,J)=0.0
      DO 2 K=1,NT
    2 B(I,K)=0.0
      X(1)=-RMAX
      Y(1)=X(1)
      DO 3 I=2,NP
      X(I)=X(I-1)+DR
    3 Y(I)=X(I)

*****************************************************************
      GO TO (4,4,29,29),MODE

*****READ VIEWING ANGLES AND SET SIN AND COSINE FOR MODE=1,2**********

    4 READ(5,103) (TH(K),K=1,NT)
      DO 5 K=1,NT
      THETA=TH(K)/57.296
      CC(K)=COS(THETA)
    5 SS(K)=SIN(THETA)

****************************************************************

      IF(MODE.EQ.1) GO TO 7

*****READ REFRACTIVE INDEX FOR MODE=2 OPERATION**********************
```

```
      DO 6 I=1,NP
    6 READ(5,103)(A(I,J),J=1,NP)
*****************************************************************************
      GO TO 9
    7 IF(KSYM.EQ.99) GO TO 13
*****SET REFRACTIVE INDEX AND WRITE SAME FOR MODE ONE OPERATION*******
      DO 8 I=1,NP
      DO 8 J=1,NP
      XI=X(I)
      YJ=Y(J)
      CALL INPUT(XI,YJ,VAL)
    8 A(I,J)=VAL
    9 WRITE(6,115)
      WRITE(6,113)
      K=1
      K21=21
   11 WRITE(6,106)
      WRITE(6,110) (X(I),I=K,K21)
      DO 12 I=1,NP
      NN=NP-I+1
   12 WRITE(6,111) Y(NN),(A(J,NN),J=K,K21)
      IF(K21.EQ.NP) GO TO 150
      K=K21+1
      K21=K21+21
      IF(K21.GT.NP) K21=NP
      GO TO 11
  150 A(1,1)=-1.0
      A(1,2)=1.0

      CALL CTRMAP(A,NMAP,NP,NP)
      WRITE(6,112)(ITT(I),I=1,12)
      CALL CONTUR(A,NP,NP,101,CL,NL,ITT,IW,IH,LTG)
      GO TO 15
*****************************************************************************
*****SET REFRACTIVE INDEX FOR AXISYMETRIC CASE*************************
   13 DO 14 I=1,NP
   14 CALL INPUT(X(I),0,A(I,N))
*****************************************************************************
   15 IF(MODE.EQ.2) GO TO 19
```

```
*****INTEGRATE FOR FINGE SHIFT FOR MODE ONE CASE*********************

      DO 18 K=1,NT
      R=-RMAX
      B(1,K)=0.0
      B(NP,K)=0.0
      DO 18 I=2,NPM1
      R=R+DR
      P1=SQRT(RM2-R**2)
      DP=2.*P1/FNP5
      P=-P1
      DO 16 J=1,NP5
      YJ=R*CC(K)+P*SS(K)
      XI=-R*SS(K)+P*CC(K)
      CALL INPUT(XI,YJ,VAL)
      P=P+DP
   16 BD(J)=VAL
      SUM=0.
      NPP2=NP5-2
      DC 17 J=1,NPP2,2
*****INTEGRATION USES SIMPSON'S RULE ********************
   17 SUM=SUM+BD(J)+4.*BD(J+1)+BD(J+2)
   18 B(I,K)=SUM*DP/3.
      GO TO 34

**********************************************************************

*****INTEGRATE FOR FINGE SHIFT FOR MODE TWO CASE*********************

   19 K=0
   20 K=K+1
      IF(K.GT.NT) GO TO 33
      IF(TH(K).EQ.0.) GO TO 23
      IF(TH(K).EQ.90.) GO TO 26
      R=-RMAX
      B(1,K)=0.0
      B(NP,K)=0.0
      DO 22 L=2,NPM1
      SUM=0.
      R=R+DR
      P1=SQRT(RM2-R**2)
      DP=2.*P1/FNP5
      P=-P1
      DO 21 LL=1,NP5
      XN=-R*SS(K)+P*CC(K)
      YN=R*CC(K)+P*SS(K)
      LINEAR INTERPOLATE FOR VALUE OF REFRACTIVE INDEX*****
```

```
      I=(XN+RMAX+DR)/DR
      J=(YN+RMAX+DR)/DR
      XD=(XN-X(I))/DR
      YD=(YN-Y(J))/DR
      VAL=A(I,J)+XD*(A(I+1,J)-A(I,J))
      VAL=VAL+YD*(A(I,J+1)+XD*(A(I+1,J+1)-A(I,J+1))-VAL)
      ***************************************************************
      SUM=SUM+VAL*DP
   21 P=P+DP
   22 B(L,K)=SUM
      GO TO 20
   23 DO 25 J=1,NP
      B(J,K)=0.0
      DO 24 I=2,NP
   24 B(J,K)=B(J,K)+ (A(I-1,J)+A(I,J))
   25 B(J,K)=DR*B(J,K)/2.
      GO TO 20
   26 DO 28 I=1,NP
      L=NP+1-I
      B(L,K)=0.0
      DO 27 J=2,NP
   27 B(L,K)=B(L,K)+A(I,J-1)+A(I,J)
   28 B(L,K)=DR*B(L,K)/2.
      GO TO 20

*************************************************************************

*****READ DATA FOR MODE THREE OR FOUR OPERATION************************

   29 DO 32 I=1,NT
      READ(5,103) TH(I),DASYM(I)
      IF(DASYM(I).EQ.1.) GO TO 30
      READ(5,103) (B(J,I),J=1,NP)
      GO TO 32
      READ AND COPY SYMETRIC DATA ************************
   30 READ(5,103) (B(J,I),J=1,N)
      L=N+1
      DO 31 J=L,NP
      K=NP-J+1
   31 B(J,I)=B(K,I)
      ***************************************************
   32 CONTINUE

*************************************************************************

   33 IF(MODE.EQ.5) GO TO 63
```

```
*****SET RADIUS VECTOR AND EXTEND FRINGE INFORMATION TO TWICE RMAX****

   34 RB(1)=-2.*RMAX
      DO 35 I=2,NPP
   35 RB(I)=RB(I-1)+DR
      DO 38 I=1,NT
      Q1=B(1,I)
      Q2=(B(2,I)-B(1,I))/DR
      CALL COEF(C1,Q2,-RMAX,E,G,C)
      DO 36 J=1,NPL
   36 BB(J,I)=F1(E,G ,C,RB(J))
      DO 37 K=1,NP
   37 BB(K+NPL,I)=B(K,I)
      C1=B(NP,I)
      C2=(B(NP,I)-B(NP-1,I))/DR
      CALL COEF(Q1,Q2, RMAX,E,G,C)
      L=NP+NPL
      DO 38 K=L,NPP
   38 BB(K,I)=F1(E,G ,C,RB(K))

**************************************************************************


*****CALCULATE VALUE OF INSIDE INTEGRAL ******************************

      DO 43 I=1,NT
      DC 43 J=1,NP
      M=NPL+J
      BD(1)=0.
      DO 39 K=1,MAX
      MKP=M+K
      MKM=M-K
      IF(MKP.GT.NPP) MKP=NPP
      IF(MKM.LT.1) MKM=1
      K1=K**2
   39 BC(K+1)=(BB(MKP,I)+BB(MKM,I)-2.*BB(M,I))/(FLOAT(K1)*DR)
      VAL=0.
      K1=1
   40 K2=K1+6
      IF(K2.GT.MAX) GO TO 41
      COTES SIXTH ORDER QUADATURE FORMULA*****************
      VAL=VAL+C1*(BD(K1)+BD(K2))+C2*(BC(K1+1)+BD(K2-1))+C3*(BD(K1+2)+BD(
     1K2-2))+C4*BD(K1+3)
      K1=K2
      GC TO 40
   41 SUM=0.
      CCNTRIBUTION OF LAST TERMS
      DO 42 K=K1,MAX
```

```
   42 SUM=SUM+BD(K)+BD(K+1)
      SUM COTES PLUS LAST TERMS PLUS INTEGRATION FROM 2 RMAX TO INFINITY
   43 B(J,I)= VAL+SUM/2.-.666667*BB(M,I)/RMAX
      IF(KSYM.LT.99) GO TO 48

*****************************************************************************

*****INTEGRATE OVER THETA FOR AXISYMETRIC CASE*************************

      DEL=-.004421
      M=1
      TH(1)=0.0
      SS(1)=0.0
      DO 44 I=2,19
      TH(I)=TH(I-1)+5.
   44 SS(I)=SIN(TH(I)/59.296)
      WRITE(6,107)
      DO 47 I=1,NP
      DO 45 K=1,19
      R=-X(I)*SS(K)
      L=(R+RMAX+DR)/DR
      IF(L.GE.NP) GO TO 460
      IF(L.LT.1) GO TO 460
      LP2=L+2
      LP1=L+1
      LM1=L-1
      IF(LP2.GT.NP) LP2=NP
      IF(LM1.LT.1) LM1=1
      P=(R-X(L))/DR
      COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(L,K))
      COF2=.5*(B(LP1,K)+B(LM1,K))-B(L,K)
      CCF1=-.1666666*B(LP2,K)+B(LP1,K)-.333333*B(LM1,K)-.5*B(L,K)
      P2=P*P
*****AMOUNT OF FILTERING DEPENDS ON FT2=FILTER*FILTER*********
   45 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(L,K)
      SUM=0.0
      TRAPEZOIDAL INTEGRATION ON THETA    *****************
      DC 46 K=2,19
      SUM=SUM+BD(K)+BD(K-1)
   46 CONTINUE
      A(I,1)=SUM*DEL
  460 CONTINUE
      OUTPUT IS DENSITY FIELD IF MODE=3*******************
      IF(MODE.LT.3) GO TO 47
      A(I,2)=RHOINF+.4443*XLAMD*A(I,1)
   47 WRITE(6,105) X(I),A(I,N),A(I,1),A(I,2),BB(NPL+I,1),B(I,1)
```

```
C*********************************************************************
      IF(MODE.LT.3) GO TO 75
      GO TO 75
   48 M=NT+1
      IF(KSYM.EQ.0) GO TO 51
      IF(KSYM.GT.4) GO TO 53
C****GENERATE ADDITIONAL DATA DEPENDING ON SYMETRY OF FIELD**********
      DT=TH(2)-TH(1)
      NTP=NT
      DO 50 J=1,KSYM
      K=J*NT
      DO 49 I=1,NTP
      KK=K+I
      TH(KK)=TH(KK-1)+DT
      KM=K-I+1
      DO 49 L=1,NP
   49 B(L,KK)=B(L,KM)
   50 NTP=2*NTP
      M=KK+1
C*********************************************************************
C****GENERATE DATA FOR 180 DEGREE VIEW*******************************
   51 TH(M)=TH(1)+180.
      DO 52 I=1,NP
      K=(NP-I+1)
   52 B(K,M)=B(I,1)
C*********************************************************************
      GO TO 55
C****GENERATE ADDITIONAL DATA FOR REPEATING DATA*********************
   53 M=180/KSYM+1
      DO 54 I=2,M
      TH(I)=TH(I-1)+FLOAT(KSYM)
      DO 54 J=1,NP
   54 B(J,I)=B(J,I-1)
   55 CONTINUE
C*********************************************************************
```

```
*****INTEGRATE ON THETA FOR ASYMETRIC FIELD***************************

      MD=M-1
      DEL=-1./(2.*3.1416*FLOAT(MD))
      DO 56 I=1,M
      CC(I)=COS(TH(I)/59.296)
   56 SS(I)=SIN(TH(I)/59.296)
      DO 61 LL= 1,NP
      J=NP+ 1-LL
      DC 60 I= 1,NP
      A(I,J)=0.
      DC 58 K=1,M
      R=Y(J)*CC(K)-X(I)*SS(K)
      NN=(R+RMAX+DR)/DR
      IF(NN.GE.NP) GO TO 60
      IF(NN.LT.1) GO TO 60
      LP2=NN+2
      LP1=NN+1
      LM1=NN-1
      IF(LP2.GT.NP) LP2=NP
      IF(LM1.LT.1) LM1=1
      P=(R-X(NN))/DR
      COF3=.1666666*(B(LP2,K)-B(LM1,K))-.5*(B(LP1,K)-B(NN,K))
      COF2=.5*(B(LP1,K)+B(LM1,K))-B(NN,K)
      CCF1=-.1666666*B(LP2,K)+B(LP1,K)-.333333*B(LM1,K)-.5*B(NN,K)
      P2=P*P
*****AMCUNT OF FILTERING DEPENDS ON FT2=FILTER*FILTER*********
   58 BD(K)=P*(P2+FT2)*COF3+(P2+.666666*FT2)*COF2+P*COF1+B(NN,K)
      INTEGRATE OVER THETA USING TRAPEZOIDAL INTEGRATION*********
      VAL=0.0
      DO 59 L=2,M
   59 VAL=VAL+BD(L)+BD(L-1)
      A(I,J)=VAL*DEL/2.
************************************************************************
   60 CONTINUE
   61 CCNTINUE

************************************************************************

      NFN=NP+NPL
      IF(MODE.LT.4) GO TO 63
      IF(MODE.EQ.4) MODE=5
      GO TO 19
   63 IF(MODE.LT.3) GO TO 65

*****CHANGE REFRACTIVE INDEX FIELD TO DENSITY FIELD*****************
```

```
 65 WRITE(6,115)
 66 WRITE(6,113)

*****WRITE REFRACTIVE INDEX OR DENSITY FIELD**************************

    K=1
    K21=21
 67 WRITE(6,106)
    WRITE(6,110) (X(I),I=K,K21)
    DO 68 I= 1,NP
    NN=NP-I+1
 68 WRITE(6,111) Y(NN),(A(J,NN),J=K,K21)
    IF(K21.EQ.NP) GO TO 690
    K=K21+1
    K21=K21+21
    IF(K21.GT.NP) K21=NP
    GC TO 67
**********************************************************************

690 A(1,1)=-1.0
    A(1,2)=1.0
    CALL CTRMAP(A,NMAP,NP,NP)
    WRITE(6,112)(ITT(I),I=1,12)
    CALL CONTUR(A,NP,NP,101,CL,NL,ITT,IW,IH,LTG)

 69 WRITE(6,116)

*****WRITE FRINGE SHIFT INFORMATION***********************************

    WRITE(6,104) (TH(K),K=1,NT)
    DC 70 I=N,NPN
 70 WRITE(6,105) RB(I),(BB(I,J),J=1,NT)
    WRITE(6,112)(ITT(I),I=1,12)


    WRITE(6,116)
    WRITE(6,104) (TH(K),K=1,NT)
    DO 700 J=1,NT
    WRITE(6,103) TH(J)
    WRITE(6,103)(BB(I,J),I=N,NPN)
700 CONTINUE
```

```
      WRITE(7,112)(IT(I),I=1,12)
      WRITE(7,103) RHOINF,XLAMD
      WRITE(7,100) MODE,NP,NT,KSYM,RMAX,FILTER
      DO 710 J=1,NT
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=N,NPN)
  710 CONTINUE

      WRITE(6,117)
      WRITE(6,104) (TH(K),K=1,M)
      DO 71 I=1,NP
   71 WRITE(6,105) X(I),(B(I,J),J=1,M)
      WRITE(6,112)(ITT(I),I=1,12)

   75 CONTINUE
      STOP
      END

      SUBROUTINE COEF(VAL,SLOPE,U,CU2,CU,CONST)
*******************************************************************
*                                                                 *
*   SUBROUTINE COEF CALCULATES THE COEFICIENTS USED BY  THE      *
*   FUNCTION (F1) TO EXPAND THE FRINGE INFCRMATION TO 2 RMAX     *
*                                                                 *
*******************************************************************
      U2=U*U
      CU2=-SLOPE/U-VAL/U2
      CU=-VAL/U-3.*U*CU2
      CONST=VAL-CU*U-CU2*U2
      RETURN
      END

      SUBROUTINE INPUT(XI,YJ,VAL)
*******************************************************************
*                                                                 *
*   SUBRCUTINE INPUT IS SUPPLIED BY THE USER FOR MODE 1          *
*   OPERATION.  THE MAIN PROGRAM PASSES THE POINT (XI,YJ) AND    *
*   'INPUT' SUPPLIES THE VALUE OF THE REFRACTIVE INDEX AT THAT   *
*   POINT USING ANY ARITHMETIC OR LCGIC STATMENT NECESSARY.      *
*                                                                 *
*******************************************************************
      VAL=0.
      VAL=F(XI,YJ)
      RETURN
      END
```

```
**********************************************************************
*                                                                    *
*    THE INPUT DATA FILES USED IN THE TESTING ARE INCLUCED          *
*                                                                    *
**********************************************************************


               CASE #1
   THE ASYMMETRIC TEST CASE OF FIGURE 8
     RUN UNDER MODE 1
     Y2=YJ*YJ
     X2=XI*XI
     VAL=(1.-Y2)*EXP(-2.*X2)
     R2=Y2+X2
     IF(R2.GT.1.5) VAL = 0.
     RETURN
     END
**********************************************************************
     NECESSARY DATA CARDS
**********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE CN (Y)
     MCDE 1 STANDARD CASE
     CASE #1
 1.176     .6941
       1        101         6          1         2.0        .5
   07.5      22.5       37.5       52.5       67.5       82.5
**********************************************************************
**********************************************************************


               CASE #3
   THE ASYMMETRIC TEST'CASE OF FIGURE 8
     RUN UNDER MODE 3
**********************************************************************
     NECESSARY DATA CARDS
**********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE CN (Y)
EVERETT INTRPL OF FIGURE #8
     CASE #3
 1.176     .6941                              KSYM   RMAX         Filter
 mode 3    NP 101       NT 6                   1   2.0000C    0.50000
**********************************************************************
     CONTINUE ENTERING FRINGE SHIFT INFORMATION
               OBTAINED FROM CASE #1
**********************************************************************
```

```
            THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                      FOR THIS CASE IS:
************************************************************************
TH(I) 7.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0       -0.18822   -0.22693   -0.20304   -0.15116
-0.08012   -0.00176    0.08060    0.16530    0.24902    0.33243    0.41315    0.49143
 0.56688    0.63918    0.70646    0.77017    0.83009    0.88627    0.93691    0.98347
 1.02598    1.06442    1.09881    1.12914    1.15541    1.17762    1.19578    1.20989
 1.21996    1.22597    1.22794    1.22587    1.21975    1.20959    1.19540    1.17717
 1.15491    1.12861    1.09828    1.06392    1.02553    0.98312    0.93669    0.88623
 0.83013    0.77014    0.70649    0.63918    0.56691    0.49149    0.41325    0.33258
 0.24880    0.16499    0.08018   -0.00230   -0.08080   -0.15035   -0.20400   -0.22594
-0.18907    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
22.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0       -0.08210   -0.11309   -0.11150   -0.09325
-0.05172    0.00029    0.05948    0.12490    0.19888    0.27284    0.35051    0.42839
 0.50575    0.58186    0.65559    0.72611    0.79366    0.85758    0.91575    0.96929
 1.01819    1.06246    1.10208    1.13706    1.16739    1.19307    1.21410    1.23048
 1.24221    1.24927    1.25167    1.24941    1.24248    1.23089    1.21462    1.19368
 1.16806    1.13777    1.10279    1.06313    1.01878    0.96975    0.91602    0.85760
 0.79361    0.72623    0.65541    0.58214    0.50613    0.42890    0.35116    0.27368
 0.19782    0.12365    0.05799   -0.00140   -0.05362   -0.09128   -0.11356   -0.11123
-0.08349    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
37.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.00633    0.00492    0.00620    0.00896
 0.02571    0.04994    0.07978    0.11559    0.16766    0.21854    0.28122    0.34803
 0.41828    0.49114    0.56893    0.64441    0.72083    0.79401    0.86161    0.92412
 0.98150    1.03370    1.08069    1.12243    1.15889    1.19001    1.21577    1.23612
 1.25103    1.26045    1.26435    1.26269    1.25543    1.24252    1.22394    1.19963
 1.16957    1.13371    1.09202    1.04445    0.99097    0.93153    0.86610    0.79464
 0.72004    0.64533    0.56784    0.49240    0.41969    0.34960    0.28295    0.22047
 0.16559    0.11342    0.07760    0.04782    0.02366    0.01076    0.00466    0.00604
 0.00567    0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0
52.50000
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
 0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
```

```
 0.0       0.0       0.0       0.0       0.03333   0.05434   0.07108   0.08521
 0.10243   0.12194   0.14333   0.16664   0.20163   0.23424   0.27833   0.32723
 0.38086   0.43898   0.50877   0.57724   0.65221   0.72459   0.79195   0.85399
 C.91073   0.96214   1.00821   1.04894   1.08431   1.11432   1.13896   1.15822
 1.17208   1.18054   1.18359   1.18122   1.17341   1.16017   1.14147   1.11732
 1.08770   1.05260   1.01201   0.96592   0.91433   0.85721   0.79458   0.72640
 0.65018   0.57933   0.50655   0.44125   0.38311   0.32944   0.28047   0.23634
 0.19967   0.16483   0.14179   0.12068   0.10140   0.08595   0.07059   0.05459
 0.03325   C.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
67.50000
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.03181   0.05717   0.08101   0.10520
 0.13010   0.15680   0.18588   0.21685   0.25177   0.28727   0.32823   0.37235
 0.41948   0.46941   0.52874   0.58699   0.65222   0.71481   0.77276   0.82613
 0.87493   0.91914   0.95877   0.99379   1.02420   1.05000   1.07118   1.08772
 1.09964   1.10691   1.10953   1.10749   1.10079   1.08941   1.07335   1.05261
 1.02718   0.99704   0.96220   0.92264   0.87835   0.82934   0.77559   0.71709
 0.64989   0.58918   0.52663   0.47135   0.42120   0.37384   0.32951   0.28838
 0.25089   0.21614   0.18539   0.15649   0.12992   0.10528   0.08101   0.05712
 0.03186   0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0
82.50000
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.02752   0.05118   0.07517   0.10129
 0.12894   0.15940   0.19399   0.23247   0.27224   0.31651   0.36336   0.41329
 0.46575   0.52001   0.57776   0.63557   0.69598   0.75454   0.80925   0.85971
 0.90592   0.94785   0.98548   1.01881   1.04781   1.07247   1.09277   1.10870
 1.12024   1.12737   1.13008   1.12835   1.12217   1.11152   1.09638   1.07674
 1.05258   1.02388   C.99063   0.95282   0.91042   0.86342   0.81181   0.75556
 0.69500   0.63643   0.57700   0.52067   0.46628   0.41372   0.36369   0.31676
 0.27207   0.23237   0.19395   0.15939   0.12895   0.10126   0.07521   0.05114
 0.02755   C.0       0.0       0.0       0.0       0.0       0.0       0.0
 0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
 C.0       0.0       0.0       0.0       0.0


                  CASE #4
         THE ASYMMETRIC TEST CASE OF FIGURE 8
       RUN UNDER MODE 3
*****************************************************************
       NECESSARY DATA CARDS
*****************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
```

```
QUARE CN (Y)
EVERETT INTRPL(LINEAR) OF FIGURE #8
     CASE #4
 1.176     .6941
         3         101          6          1   2.00000   0.50000
*********************************************************************
     CONTINUE ENTERING FRINGE SHIFT INFORMATICN
               OBTAINED FROM CASE #1
*********************************************************************
     THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                    FOR THIS CASE IS:
*********************************************************************
  7.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0       -0.18822   -0.22693   -0.20304   -0.15116
 -0.08012   -0.00176    0.08060    0.16530    0.24902    0.33243    0.41315    0.49143
  0.56688    0.63918    0.70646    0.77017    0.83009    0.88627    0.88627    0.88627
  0.88627    0.88626    0.88626    0.88626    0.88626    0.88626    0.88626    0.88625
  0.88625    0.88625    0.88625    0.88625    0.88625    0.88625    0.88624    0.88624
  0.88624    0.88624    0.88624    0.88624    0.88623    0.88623    0.88623    0.88623
  0.83013    0.77014    0.70649    0.63918    0.56691    0.49149    0.41325    0.33258
  0.24880    0.16499    0.08018   -0.00230   -0.08080   -0.15035   -0.20400   -0.22594
 -0.18907    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
 22.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0       -0.08210   -0.11309   -0.11150   -0.09325
 -0.05172    0.00029    0.05948    0.12490    0.19888    0.27284    0.35051    0.42839
  0.50575    0.58186    0.65559    0.72611    0.79366    0.85758    0.85758    0.85758
  0.85758    0.85758    0.85758    0.85758    0.85759    0.85759    0.85759    0.85759
  0.85759    0.85759    0.85759    0.85759    0.85759    0.85759    0.85759    0.85759
  0.85759    0.85760    0.85760    0.85760    0.85760    0.85760    0.85760    0.85760
  0.79361    0.72623    0.65541    0.58214    0.50613    0.42890    0.35116    0.27368
  0.19782    0.12365    0.05799   -0.00140   -0.05362   -0.09128   -0.11356   -0.11123
 -0.08349    0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0
 37.50000
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.0        0.0        0.0        0.0
  0.0        0.0        0.0        0.0        0.00633    0.00492    0.00620    0.00896
  0.02571    0.04994    0.07978    0.11559    0.16766    0.21854    0.28122    0.34803
  0.41828    0.49114    0.56893    0.64441    0.72083    0.79401    0.79403    0.79406
  0.79408    0.79411    0.79413    0.79416    0.79418    0.79420    0.79423    0.79425
  0.79428    0.79430    0.79432    0.79435    0.79437    0.79440    0.79442    0.79445
```

0.79447	0.79449	0.79452	0.79454	0.79457	0.79459	0.79462	0.79464
0.72004	0.64533	0.56784	0.49240	0.41969	0.34960	0.28295	0.22047
0.16559	0.11342	0.07760	0.04782	0.02366	0.01076	0.00466	0.00604
0.00567	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
52.5CC00							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.03333	0.05434	0.07108	0.08521
0.10243	0.12194	0.14333	0.16664	0.20163	0.23424	0.27833	0.32723
0.38086	0.43898	0.50877	0.57724	0.65221	0.72459	0.72466	0.72473
0.72480	0.72487	0.72494	0.72501	0.72508	0.72515	0.72522	0.72529
0.72536	0.72543	0.72549	0.72556	0.72563	0.72570	0.72577	0.72584
0.72591	0.72598	0.72605	0.72612	0.72619	0.72626	0.72633	0.72640
0.65018	0.57933	0.50655	0.44125	0.38311	0.32944	0.28047	0.23634
0.19967	0.16483	0.14179	0.12068	0.10140	0.08595	0.07059	0.05459
0.03325	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
67.50C00							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.03181	0.05717	0.08101	0.10520
0.13010	0.15680	0.18588	0.21685	0.25177	0.28727	0.32823	0.37235
0.41948	0.46941	0.52874	0.58699	0.65222	0.71481	0.71490	0.71499
0.71507	0.71516	0.71525	0.71534	0.71542	0.71551	0.71560	0.71569
0.71577	0.71586	0.71595	0.71604	0.71613	0.71621	0.71630	0.71639
0.71648	0.71656	0.71665	0.71674	0.71683	0.71691	0.71700	0.71709
0.64989	0.58918	0.52663	0.47135	0.42120	0.37384	0.32951	0.28838
0.25C89	0.21614	0.18539	0.15649	0.12992	0.10528	0.08101	0.05712
0.03186	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
82.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.02752	0.05118	0.07517	0.10129
0.12894	0.15940	0.19399	0.23247	0.27224	0.31651	0.36336	0.41329
0.46575	0.52001	0.57776	0.63557	0.69598	0.75454	0.75458	0.75462
0.75466	0.75470	0.75474	0.75478	0.75481	0.75485	0.75489	0.75493
0.75497	0.75501	0.75505	0.75509	0.75513	0.75517	0.75521	0.75525
0.75529	0.75532	0.75536	0.75540	0.75544	0.75548	0.75552	0.75556
0.69500	0.63643	0.57700	0.52067	0.46628	0.41372	0.36369	0.31676
0.27207	0.23237	0.19395	0.15939	0.12895	0.10126	0.07521	0.05114
0.02755	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			

```
                         CASE #5
     THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
     CENTER BY 0.25 IN THE X AND Y DIRECTIONS
     RUN UNDER MODE 1
     YJ=YJ-0.25
     Y2=YJ*YJ
     XI=XI-0.25
     X2=XI*XI
     VAL=(1.-Y2)*EXP(-2.*X2)
     R2=Y2+X2
     IF(R2.GT.1.5) VAL = 0.
     RETURN
     END
***********************************************************************
     NECESSARY DATA CARDS
***********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE ON (Y)
     MODE 1 (DISPLACED) STANDARD CASE
CASE #5
 1.176     .6941
    1        101        12         0      2.0        .5
  07.5      22.5      37.5      52.5      67.5      82.5      97.5      112.5
 127.5     142.5     157.5     172.5
***********************************************************************
***********************************************************************

                         CASE #7
     THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
     CENTER BY 0.25 IN THE X AND Y DIRECTIONS
     RUN UNDER MODE 3
***********************************************************************
     NECESSARY DATA CARDS
***********************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE CN (Y)
EVERETT INTRPL OF FIGURE #8 (DISPLACED)
     CASE #7
 1.176     .6941
    3        101        12         0      2.0        .5
**********************************************************************
     CONTINUE ENTERING FRINGE SHIFT INFORMATION
              OBTAINED FROM CASE #5
**********************************************************************
     THE MODIFIED OUTPUT FRINGE SHIFT INFORMATION
```

FOR THIS CASE IS:

****

7.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-0.13023	-0.22792	-0.21639	-0.17190	-0.10786	-0.03227	0.04915
0.13230	0.21709	0.30073	0.38260	0.46169	0.53802	0.60989	0.67788
0.74199	0.80220	0.85850	0.91088	0.95932	1.00383	1.04438	1.08097
1.11358	1.14221	1.16685	1.18747	1.20408	1.21666	1.22519	1.22968
1.23010	1.22646	1.21872	1.20690	1.19096	1.17091	1.14674	1.11842
1.08448	1.04690	1.00441	0.95781	0.90730	0.85223	0.79338	0.73177
0.66494	0.59461	0.52006	0.44302	0.36309	0.28102	0.19758	0.11256
0.02868	-0.05159	-0.12560	-0.18595	-0.22272	-0.21363	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
22.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.05321
-0.10985	-0.11971	-0.10013	-0.06836	-0.02300	0.03531	0.09879	0.17160
0.24465	0.32121	0.39935	0.47700	0.55351	0.62740	0.69711	0.76289
0.82468	0.88245	0.93616	0.98574	1.03117	1.07239	1.10937	1.14204
1.17038	1.19433	1.21384	1.22888	1.23940	1.24536	1.24670	1.24338
1.23536	1.22259	1.20503	1.18263	1.15535	1.12314	1.08596	1.04375
0.99434	0.94047	0.88204	0.81930	0.75250	0.68268	0.61059	0.53539
0.45812	0.38087	0.30294	0.22608	0.15183	0.08195	0.01962	-0.03300
-0.07863	-0.10565	-0.11872	-0.09991	-0.00586	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
37.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.00608	0.00508	0.00287
0.01097	0.02244	0.04074	0.07147	0.10856	0.15807	0.20954	0.27345
0.33753	0.40841	0.48087	0.55761	0.63255	0.70929	0.78210	0.85016
0.91341	0.97177	1.02517	1.07354	1.11682	1.15493	1.18780	1.21536
1.23753	1.25426	1.26547	1.27109	1.27105	1.26527	1.25369	1.23624
1.21285	1.18344	1.14795	1.10630	1.05843	1.00426	0.94373	0.87676
0.80498	0.73176	0.65544	0.58059	0.50328	0.43136	0.35962	0.29398
0.22605	0.17588	0.12500	0.08315	0.05138	0.02831	0.01399	0.00700
0.00441	0.00614	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
52.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.03739	0.05728	0.07287	0.08734	0.10579

0.12320	0.14594	0.17072	0.20480	0.24027	0.28602	0.33741	0.39290
0.45313	0.51624	0.59054	0.65924	0.73348	0.80990	0.87996	0.94264
0.99810	1.04649	1.08797	1.12270	1.15082	1.17251	1.18790	1.19716
1.20045	1.19791	1.18971	1.17600	1.15693	1.13267	1.10337	1.06918
1.03027	0.98677	0.93886	0.88669	0.83041	0.77018	0.70615	0.63848
0.56495	0.49683	0.43683	0.37237	0.32079	0.26958	0.23162	0.19364
0.16064	0.13951	0.11777	0.09926	0.08287	0.06915	0.05184	0.02845
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
67.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.00196	0.04217	0.06692	0.08968	0.11442	0.13980	0.16770	0.19773
0.22941	0.26507	0.30178	0.34431	0.39062	0.43890	0.49051	0.55138
0.61209	0.67023	0.73846	0.80225	0.87492	0.94171	0.99402	1.03824
1.07471	1.10375	1.12566	1.14078	1.14941	1.15189	1.14852	1.13964
1.12555	1.10658	1.08305	1.05527	1.02358	0.98827	0.94969	0.90814
0.86394	0.81742	0.76889	0.71868	0.66710	0.61447	0.56111	0.50734
0.44903	0.40071	0.35524	0.31279	0.27299	0.23597	0.20452	0.17372
0.14630	0.12003	0.09564	0.07210	0.04863	0.01902	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
82.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03668
0.06042	0.08471	0.11167	0.13996	0.17294	0.20819	0.24621	0.28930
0.33364	0.38227	0.43338	0.48724	0.54205	0.59942	0.65905	0.71769
0.77761	0.83455	0.89165	0.94351	0.99909	1.04716	1.07712	1.10078
1.11839	1.13021	1.13650	1.13751	1.13351	1.12474	1.11147	1.09395
1.07244	1.04720	1.01848	0.98655	0.95165	0.91405	0.87400	0.83176
0.78758	0.74174	0.69447	0.64604	0.59671	0.54673	0.49636	0.44585
0.39427	0.34554	0.29899	0.25639	0.21654	0.18042	0.14745	0.11807
0.09035	0.06615	0.04324	0.01628	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
97.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.02820	0.05137	0.07587
0.10064	0.12860	0.16003	0.19471	0.23229	0.27323	0.31668	0.36459
0.41434	0.46603	0.52151	0.57739	0.63538	0.69608	0.75289	0.81303
0.86940	0.92737	0.98068	1.03256	1.07850	1.12107	1.14828	1.16791
1.18037	1.18602	1.18525	1.17845	1.16599	1.14825	1.12563	1.09849
1.06724	1.03223	0.99387	0.95253	0.90859	0.86244	0.81445	0.76502
0.71452	0.66334	0.61185	0.56045	0.50950	0.45941	0.41053	0.36327
0.31639	0.27181	0.23113	0.19408	0.15964	0.12821	0.10094	0.07486

0.05150	0.02738	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
112.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.03671	0.06136	0.08493	0.10895
0.13461	0.16143	0.19016	0.22210	0.25748	0.29488	0.33501	0.38241
0.4284C	0.47873	0.53581	0.59902	0.65801	0.72601	0.79164	0.86066
0.92928	0.98783	1.05143	1.11083	1.16453	1.21169	1.19805	1.18113
1.16111	1.13820	1.11256	1.08441	1.05392	1.02128	0.98669	C.95032
0.91238	0.87305	0.83252	0.79098	0.74862	0.70563	0.66219	0.61850
0.57475	0.53112	0.48780	0.44499	0.40287	0.36163	0.32146	0.28255
0.24418	0.21101	0.18033	0.15259	0.12547	0.10095	0.07740	0.05373
0.02686	C.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
127.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.02658	0.05031	0.06751	0.08242	0.09867
0.11565	0.13537	0.15930	0.19096	0.2274C	0.26803	0.31298	0.37054
0.42826	0.49427	0.55980	0.63216	0.70885	0.77984	0.85719	0.92943
1.00122	1.06956	1.13235	1.18920	1.23928	1.28186	1.28639	1.28296
1.272C8	1.25431	1.23018	1.20023	1.16498	1.12498	1.08076	1.03287
0.98183	0.92818	0.87247	0.81522	0.75697	0.69826	0.63962	0.58159
0.52472	0.46952	0.41655	0.36633	0.31941	0.27632	0.23759	0.20376
C.17340	0.14988	0.12273	0.10758	0.08992	0.07460	0.05834	0.03948
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
142.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.00545	0.00408	0.00485	0.0C895	0.01976
0.04371	0.07220	0.10576	0.15493	0.20355	0.26392	0.33416	0.40218
0.47495	0.55145	0.62638	0.70273	0.77597	0.84909	0.91799	0.98441
1.04541	1.10166	1.15254	1.19762	1.23663	1.26931	1.26799	1.26087
1.24827	1.23051	1.20791	1.18079	1.14946	1.11423	1.07544	1.03339
0.98840	0.94079	0.89087	0.83897	0.7854C	0.73048	0.67453	0.61787
0.56080	0.50365	0.44674	0.39038	0.33490	0.28060	0.22781	0.17684
0.12590	0.08429	0.05365	0.02801	0.01099	0.00407	0.00541	0.00484
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
157.500C0							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

```
  0.0       0.0       0.0       0.0      -0.08987  -0.11626  -0.11245  -0.08521
 -0.04636   0.00831   0.06964   0.13709   0.21008   0.28663   0.36423   0.44164
  0.51894   0.59428   0.66775   0.73774   0.80473   0.86812   0.92812   0.98271
  1.03398   1.08017   1.12132   1.15834   1.19002   1.21685   1.23329   1.24406
  1.24933   1.24927   1.24407   1.23390   1.21893   1.19935   1.17533   1.14704
  1.11467   1.07839   1.03837   0.99480   0.94785   0.89770   0.84452   0.78849
  0.72979   0.66859   0.60507   0.53941   0.47178   0.40236   0.33133   0.25886
  0.18562   0.11218   0.04893  -0.01192  -0.06005  -0.09448  -0.11646  -0.11135
 -0.07193   0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0
172.50000
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0      -0.19214  -0.22718  -0.20347
 -0.14890  -0.07939  -0.00099   0.08203   0.16579   0.25050   0.33353   0.41442
  0.49311   0.56750   0.63965   0.70689   0.77149   0.83088   0.88747   0.93913
  0.98826   1.03143   1.07111   1.10619   1.13823   1.16517   1.18503   1.20083
  1.21259   1.22032   1.22405   1.22380   1.21958   1.21141   1.19932   1.18332
  1.16343   1.13968   1.11208   1.08065   1.04542   1.00639   0.96360   0.91705
  0.86678   0.81279   0.75511   0.69377   0.62877   0.56013   0.48789   0.41205
  0.33161   0.24794   0.16397   0.07949  -0.00292  -0.08149  -0.15018  -0.20405
 -0.22861  -0.18649   0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
  0.0       0.0       0.0       0.0       0.0

                          CASE #8
    THE ASYMMETRIC TEST CASE OF FIGURE 8, DISPLACED FROM THE
    CENTER BY 0.25 IN THE X AND Y DIRECTIONS
    RUN UNDER MODE 3
************************************************************
    NECESSARY DATA CARDS
************************************************************
VERETT ASYMMETRIC TEST GAUSSIAN ON (X)
QUARE ON (Y)
    CASE #8
 1.176    .6941
      3      101       12        0      2.0       .5
************************************************************
    CONTINUE ENTERING FRINGE SHIFT INFORMATION
            OBTAINED FROM CASE #5
************************************************************
    THE MODIFIED OUTPUT FRINGE SHIFT INFORMATICN
                  FOR THIS CASE IS:
************************************************************
  7.50000
```

0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	-0.13023	-0.22792	-0.21639	-0.17190	-0.10786	-0.03227	0.04915
0.13230	0.21709	0.30073	0.38260	0.46169	0.53802	0.56034	0.58267
0.60499	0.62731	0.64964	0.67196	0.69428	0.71660	0.73893	0.76125
0.78357	0.80590	0.82822	0.85054	0.87287	0.89519	0.91751	0.93983
0.96216	0.98448	1.00680	1.02913	1.05145	1.07377	1.09610	1.11842
1.08448	1.04690	1.00441	0.95781	0.90730	0.85223	0.79338	0.73177
0.66494	0.59461	0.52006	0.44302	0.36309	0.28102	0.19758	0.11256
0.02868	-0.05159	-0.12560	-0.18595	-0.22272	-0.21363	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
22.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.05321
-0.10985	-0.11971	-0.10013	-0.06836	-0.02300	0.03531	0.09879	0.17160
0.24465	0.32121	0.39935	0.47700	0.55351	0.62740	0.64341	0.65943
0.67544	0.69145	0.70747	0.72348	0.73949	0.75551	0.77152	0.78753
0.80355	0.81956	0.83557	0.85159	0.86760	0.88362	0.89963	0.91564
0.93166	0.94767	0.96368	0.97970	0.99571	1.01172	1.02774	1.04375
0.99434	0.94047	0.88204	0.81930	0.75250	0.68268	0.61059	0.53539
0.45812	0.38087	0.30294	0.22608	0.15183	0.08195	0.01962	-0.03300
-0.07863	-0.10565	-0.11872	-0.09991	-0.00586	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
37.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.00608	0.00508	0.00287
0.01097	0.02244	0.04074	0.07147	0.10856	0.15807	0.20954	0.27345
0.33753	0.40841	0.48087	0.55761	0.63255	0.70929	0.71573	0.72217
0.72861	0.73505	0.74150	0.74794	0.75438	0.76082	0.76726	0.77370
0.78014	0.78658	0.79302	0.79947	0.80591	0.81235	0.81879	0.82523
0.83167	0.83811	0.84455	0.85100	0.85744	0.86388	0.87032	0.87676
0.80498	0.73176	0.65544	0.58059	0.50328	0.43136	0.35962	0.29398
0.22605	0.17588	0.12500	0.08315	0.05138	0.02831	0.01399	0.00700
0.00441	0.00614	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
52.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.03739	0.05728	0.07287	0.08734	0.10579
0.12320	0.14594	0.17072	0.20480	0.24027	0.28602	0.33741	0.39290
0.45313	0.51624	0.59054	0.65924	0.73348	0.80990	0.80331	0.79671
0.79012	0.78353	0.77693	0.77034	0.76375	0.75716	0.75056	0.74397

0.73738	0.73078	0.72419	0.71760	0.71100	0.70441	0.69782	0.69122
0.68463	0.67804	0.67145	0.66485	0.65826	0.65167	0.64507	0.63848
0.56495	0.49683	0.43683	0.37237	0.32079	0.26958	0.23162	0.19364
0.16064	0.13951	0.11777	0.09926	0.08287	0.06915	0.05184	0.02845
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
67.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.00196	0.04217	0.06692	0.08968	0.11442	0.13980	0.16770	0.19773
0.22941	0.26507	0.30178	0.34431	0.39062	0.43890	0.49051	0.55138
0.61209	0.67023	0.73846	0.80225	0.87492	0.94171	0.92500	0.90830
0.89159	0.87488	0.85818	0.84147	0.82476	0.80806	0.79135	0.77464
0.75794	0.74123	0.72453	0.70782	0.69111	0.67441	0.65770	0.64099
0.62429	0.60758	0.59087	0.57417	0.55746	0.54075	0.52405	0.50734
0.44903	0.40071	0.35524	0.31279	0.27299	0.23597	0.20452	0.17372
0.14630	0.12003	0.09564	0.07210	0.04863	0.01902	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
82.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.03668
0.06042	0.08471	0.11167	0.13996	0.17294	0.20819	0.24621	0.28930
0.33364	0.38227	0.43338	0.48724	0.54205	0.59942	0.65905	0.71769
0.77761	0.83455	0.89165	0.94351	0.99909	1.04716	1.02403	1.00090
0.97778	0.95465	0.93152	0.90840	0.88527	0.86214	0.83901	0.81589
0.79276	0.76963	0.74651	0.72338	0.70025	0.67712	0.65400	0.63087
0.60774	0.58461	0.56149	0.53836	0.51523	0.49210	0.46898	0.44585
0.39427	0.34554	0.29899	0.25639	0.21654	0.18042	0.14745	0.11807
0.09035	0.06615	0.04324	0.01628	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
97.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.02820	0.05137	0.07587
0.10064	0.12860	0.16003	0.19471	0.23229	0.27323	0.31668	0.36459
0.41434	0.46603	0.52151	0.57739	0.63538	0.69608	0.75289	0.81303
0.86940	0.92737	0.98068	1.03256	1.07850	1.12107	1.09192	1.06278
1.03363	1.00449	0.97534	0.94619	0.91705	0.88790	0.85876	0.82961
0.80046	0.77132	0.74217	0.71302	0.68388	0.65473	0.62559	0.59644
0.56729	0.53815	0.50900	0.47986	0.45071	0.42156	0.39242	0.36327
0.31639	0.27181	0.23113	0.19408	0.15964	0.12821	0.10094	0.07486
0.05150	0.02738	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

0.0	0.0	0.0	0.0	0.0			
112.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.03671	0.06136	0.08493	0.10895
0.13461	0.16143	0.19016	0.22210	0.25748	0.29488	0.33501	0.38241
0.42840	0.47873	0.53581	0.59902	0.65801	0.72601	0.79164	0.86066
0.92928	0.98783	1.05143	1.11C83	1.16453	1.21169	1.17595	1.14022
1.10448	1.06875	1.03301	0.99727	0.96154	0.92580	0.89007	0.85433
C.81859	0.78286	0.74712	0.71138	0.67565	0.63991	0.60418	0.56844
0.53270	0.49697	0.46123	0.42549	0.38976	0.35402	0.31829	0.28255
0.24418	0.21101	0.18033	0.15259	0.12547	0.10095	0.07740	0.05373
0.02686	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
127.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.02658	0.05031	0.06751	0.08242	0.09867
0.11565	0.13537	0.15930	0.19096	0.22740	0.26803	0.31298	C.37054
0.42826	0.49427	0.55980	0.63216	0.70885	0.77984	0.85719	0.92943
1.00122	1.06956	1.13235	1.18920	1.23928	1.28186	1.24039	1.19893
1.15746	1.11600	1.07453	1.03307	0.99160	0.95014	0.90867	0.86721
0.82574	0.78428	0.74281	0.70135	0.65988	0.61841	0.57695	0.53548
0.49402	0.45255	0.41109	0.36962	0.32816	0.28669	0.24523	0.20376
0.17340	0.14988	0.12273	0.10758	0.08992	0.07460	0.05834	0.03948
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
142.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.00545	0.00408	0.00485	C.00895	0.01976
0.04371	0.07220	0.10576	0.15493	0.20355	0.26392	0.33416	0.40218
0.47495	0.55145	0.62638	0.70273	0.77597	0.84909	0.91799	0.98441
1.04541	1.10166	1.15254	1.19762	1.23663	1.26931	1.22729	1.18527
1.14326	1.10124	1.05922	1.01720	0.97518	0.93317	0.89115	0.84913
0.80711	0.76509	0.72308	0.68106	0.63904	0.59702	0.55500	0.51299
C.47097	0.42895	0.38693	0.34491	0.30290	0.26088	0.21886	0.17684
0.12590	0.08429	0.05365	0.02801	0.01099	0.00407	0.00541	0.00484
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
157.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	-0.08987	-0.11626	-0.11245	-C.08521
-0.04636	0.00831	0.06964	0.13709	0.21008	0.28663	0.36423	0.44164
0.51894	0.59428	0.66775	0.73774	0.80473	0.86812	0.92812	0.98271

1.03398	1.08017	1.12132	1.15834	1.19002	1.21685	1.18000	1.14316
1.10631	1.06947	1.03262	0.99578	0.95893	0.92208	0.88524	0.84839
0.81155	0.77470	0.73786	0.70101	0.66416	0.62732	0.59047	0.55363
0.51678	0.47993	0.44309	0.40624	0.36940	0.33255	0.29571	0.25886
0.18562	0.11218	0.04893	-0.01192	-0.06005	-0.09448	-0.11646	-0.11135
-0.07193	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			
172.50000							
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	-0.19214	-0.22718	-0.20347
-0.14890	-0.07939	-0.00099	0.08203	0.16579	0.25050	0.33353	0.41442
0.49311	0.56750	0.63965	0.70689	0.77149	0.83088	0.88747	0.93913
0.98826	1.03143	1.07111	1.10619	1.13823	1.16517	1.13620	1.10724
1.07827	1.04930	1.02034	0.99137	0.96241	0.93344	0.90447	0.87551
0.84654	0.81758	0.78861	0.75964	0.73068	0.70171	0.67275	0.64378
0.61481	0.58585	0.55688	0.52791	0.49895	0.46998	0.44102	0.41205
0.33161	0.24794	0.16397	0.07949	-0.00292	-0.08149	-0.15018	-0.20405
-0.22861	-0.18649	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.0	0.0	0.0	0.0	0.0			

```
*************************************************************************
*                                                                       *
*                        ADDITIONAL SUBRCUTINES                         *
*                                                                       *
*************************************************************************


      SUBROUTINE CTRMAP(A,NMAP,N,M)

  THIS SUBROUTINE WILL GIVE A MAP OF THE NUMBERS CONTAINED ARRAY A
  FOUR PARAMETERS MUST BE FURNISHED TO THE SUBRCUTINE

           A IS THE NAME OF THE ARRAY TO BE MAPPED
           N IS THE NUMBER OF LINES IN THE MAP
           M IS THE WIDTH OF THE LINE, MAXIMUM IS 115
           NMAP IS A FIXED POINT IDENTIFICATICN NUMBER FOR THE MAP

           TWENTY SYMBOLS ARE USED IN THE PRODUCTION OF THE MAP
           THEY ARE: A,B,C,D,E,F,G,H,I,J,,,O,,,Q,R,S,T,U,V,W,X,Y,Z.

           AT THE TOP OF THE MAP THE VALUES OF THE SYMBOLS ARE LISTED
           THE USER SHOULD REALIZE THAT THIS IS AN OUTPUT SUBROUTINE
           THAT WILL PRODUCE A DIGITAL PLOT EVERY TIME IT IS CALLED

           THE USER IS ALSO WARNED THAT THIS SUBROUTINE IS NCT GOING
           TO INTERPOLATE FOR SUPPLEMENTARY POINTS, THE MAP IS
           PRODUCED WITH THE ARRAY A EXCLUSIVELY

  CODED BY:    PROFESSOR GILLES CANTIN, (59CI) IN 1964 FOR THE CDC/1604
  REVISED AND ADAPTED FOR THE IBM/67  SEVERAL TIMES , BY THE AUTHOR
  THIS VERSION IS DATED OCTOBER 1,1969.

      DIMENSION LINE(115),ISYMB(42),BV(21),A(N,M)
      DATA ISYMB/1H ,1HO,1H ,1HA,1H ,1HB,1H ,1HC,1H ,1HD,1H ,1HE
     1,1H ,1HF,1H ,1HG,1H ,1HH,1H ,1HI,1H ,1HJ,1H ,1HQ,1H ,1HR,1H ,1HS,
     21H ,1HT,1H ,1HU,1H ,1HV,1H ,1HW,1H ,1HX,1H ,1HY,1H ,1HZ/
      DATA IBLK/1H /
      AMIN=1.E+70
      DO 6 I=1,N
      DO 5 J=1,M
    5 AMIN=AMIN1(AMIN,A(I,J)).
    6 CCNTINUE
```

```
      DO 8 I=1,N                                                        CTR00360
      DO 7 J=1,M                                                        CTR00370
    7 A(I,J)=A(I,J)-AMIN                                                CTR00380
    8 CONTINUE                                                          CTR00390
      AMAX=-1.E+70                                                      CTR00400
      DO 11 I=1,N                                                       CTR00410
      DO 10 J=1,M                                                       CTR00420
   10 AMAX=AMAX1(AMAX,A(I,J))                                           CTR00430
   11 CONTINUE                                                          CTR00440
      RGE=AMAX                                                          CTR00450
      IF(ABS(RGE)-1.0E-10) 12,12,13                                     CTR00460
   12 WRITE(6,1000)                                                     CTR00470
      WRITE(6,1400) RGE,AMAX,AMIN                                       CTR00480
 1400 FORMAT(//,5X,13H THE RANGE IS,E15.6,/,5X,13H   MAXIMUM IS,E15.6,/,CTR00490
     15X,13H   MINIMUM IS,E15.6)                                        CTR00500
      RETURN                                                            CTR00510
   13 CONTINUE                                                          CTR00520
      SCF=40./AMAX                                                      CTR00530
      DO 21 I=1,N                                                       CTR00540
      DO 20 J=1,M                                                       CTR00550
   20 A(I,J)=SCF*A(I,J)                                                 CTR00560
   21 CONTINUE                                                          CTR00570
      DO 30 I=1,21                                                      CTR00580
      AI=FLOAT(I-1)                                                     CTR00590
   30 BV(I)=(2.*AI/SCF)+AMIN                                            CTR00600
      WRITE(6,1000)                                                     CTR00610
      WRITE(6,1050)                                                     CTR00620
      WRITE(6,1300) BV(1),BV(1),BV(21)                                  CTR00630
      WRITE(6,1100) BV(2),BV(3),BV(4),BV(5),BV(6)                       CTR00640
      WRITE(6,1200) BV(7),BV(8),BV(9),BV(10),BV(11)                     CTR00650
      WRITE(6,1210) BV(12),BV(13),BV(14),BV(15),BV(16)                  CTR00660
      WRITE(6,1220) BV(17),BV(18),BV(19),BV(20),BV(21)                  CTR00670
      WRITE(6,1050)                                                     CTR00680
      M1=M+1                                                            CTR00690
      DO 50 K=1,N                                                       CTR00700
      DO 40 J=1,M                                                       CTR00710
      AJ=A(K,J)+2.50001                                                 CTR00720
      JJ=INT(AJ)                                                        CTR00730
   40 LINE(J)=ISYMB(JJ)                                                 CTR00740
      IF(M1-115) 41,41,46                                               CTR00750
   41 CONTINUE                                                          CTR00760
      DO 45 I=M1,115                                                    CTR00770
   45 LINE(I)=IBLK                                                      CTR00780
   46 CONTINUE                                                          CTR00790
      WRITE(6,2000) LINE                                                CTR00800
   50 CONTINUE                                                          CTR00810
      DO 61 I=1,N                                                       CTR00820
      DO 60 J=1,M                                                       CTR00830
```

```
   60 A(I,J)=A(I,J)/SCF +AMIN
   61 CONTINUE
      WRITE(6,2500) NMAP
 2500 FORMAT(//,5X,4H MAP,I3)
 1000 FORMAT(1H1)
 1050 FORMAT(//)
 1100 FORMAT(5X,3H A=,F8.3,3X,3H B=,F8.3,3X,3H C=,F8.3,3X,3H D=,F8.3,
     13X,3H E=,F8.3)
 1200 FORMAT(5X,3H F=,F8.3,3X,3H G=,F8.3,3X,3H H=,F8.3,3X,3H I=,F8.3,
     13X,3H J=,F8.3)
 1210 FORMAT(5X,3H Q=,F8.3,3X,3H R=,F8.3,3X,3H S=,F8.3,3X,3H T=,F8.3,
     13X,3H U=,F8.3)
 1220 FORMAT(5X,3H V=,F8.3,3X,3H W=,F8.3,3X,3H X=,F8.3,3X,3H Y=,F8.3,
     13X,3H Z=,F8.3)
 1300 FORMAT(5X,3H O=,F10.6,5X,7H RANGE(,E15.6,5X,E15.6,2H ))
 2000 FORMAT(2X,115A1)
      END
```

```
**********************************************************************
**********************************************************************
```

```
.......................................................................
```

SUBROUTINE CONTUR

1. IDENTIFICATION

   A. NAME: GENERATE CCNTOUR GRAPH (CCNTUR) - J5

   B. PROGRAMMER: BERNADETTE R.PEAVEY, 7 JULY 1969

2. PURPOSE

   CONTUR GENERATES A CONTOUR GRAPH ON WHICH ONE CR MCRE (USUALLY MORE) CONTOUR LEVELS ARE DRAWN; THAT IS, GIVEN A MATRIX CF NUMERICAL VALUES OF Z=F(X,Y), CCNTUR FINDS THE LCCI OF SPECIFIED DISCRETE VALUES OF Z AND PLOTS THESE LOCI (CONTOUR LINES) USING THE OFFLINE PLOTTER.

3. USAGE

   A. DEFINITIONS

   IN WHAT FOLLOWS THE WORD GRAPH OR CONTOUR GRAPH WILL BE

```
TAKEN TO MEAN A COMPLETE CONTOUR PICTURE; THAT IS, ONE PIECE
OR FRAME OF GRAPH PAPER ON WHICH ONE CR MORE (USUALLY MORE)
CONTOUR LEVELS ARE DRAWN.

    A CONTOUR OR CONTOUR LEVEL WILL MEAN THE PLCT OF THE LOCUS
ON THE XY PLANE OF ALL Z EQUAL TO A CONSTANT VALUE. NORMALLY,
SUCH A CONTOUR WILL CONTAIN MORE THAN ONE CONTOUR SEGMENT.

    A CONTOUR SEGMENT IS EITHER A CLOSED FIGURE (INTERIOR
CONTOUR SEGMENT) OR A CURVE, EACH END OF WHICH TERMINATES AT
A MARGIN OF THE CONTOUR GRAPH (EXTERICR CONTOUR SEGMENT). IT
REPRESENTS, IN GENERAL, ONLY A PART OF THE LOCUS ON THE XY
PLANE OF ALL Z EQUAL TO SOME VALUE. FCR EXAMPLE, IF Z=F(X,Y)
REPRESENTS A RANGE OF THREE MOUNTAINS CF EQUAL ALTITUDE, EACH
A CIRCULAR CONE, THEN EVERY CONTOUR SEGMENT WOULD APPEAR AS A
CIRCLE. THREE CIRCLES, ONE FCR EACH MOUNTAIN, WOULD MAKE UP
ONE CONTOUR OR CONTOUR LEVEL.  THE COMPLETE GRAPH WOULD APPEAR
AS THREE NESTS OF CONCENTRIC CIRCLES.

B. CALLING STATEMENT

   CALL CONTUR(AM,M,N,MX,CL,NL,TITLE,IW,IH,LTG)

   WHERE:

   1) AM IS THE REAL*4 DATA MATRIX TO BE CONTOURED AND PLOTTED.
         IT IS A TWO-DIMENSIONAL ARRAY WHOSE ROW DIMENSION IS
         PASSED TO CONTUR AS THE PARAMETER MX.

   2) M IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF ROWS IN THE
        DATA MATRIX TO BE CONTOURED.

   3) N IS AN INTEGER VARIABLE WHICH IS THE NUMBER OF COLUMNS IN
        THE DATA MATRIX TO BE CONTOURED.

   4) MX IS AN INTEGER WHICH SPECIFIES THE ROW DIMENSION OF AM.
         THIS IS THE EXACT NUMBER APPEARING IN THE DIMENSION
         STATEMENT DEFINING AM.

   5) CL IS A REAL*4 ARRAY CONTAINING THE CONTOUR LEVELS TO BE
         PLOTTED DIMENSIONED AT LEAST CL(|NL|).

   6) NL IS AN INTEGER VARIABLE WHOSE ABSOLUTE VALUE IS THE
         NUMBER OF CONTOUR LEVELS TO BE FOUND FOR THIS GRAPH. IF
         NL IS NEGATIVE THEN CONTUR SCANS THE DATA MATRIX FOR THE
         LOWEST AND HIGHEST LEVELS TO DETERMINE THE DELTA VALUE
         FOR PRODUCING |NL| LEVELS OF CONTOURING. IF NL IS
         POSITIVE, THEN CONTUR ASSUMES THE CL ARRAY CONTAINS
```

```
      NL ENTRIES OF CONTOUR LEVELS TO BE PLOTTED.

  7) TITLE IS A REAL*8 ARRAY DIMENSIONED TITLE(12). CONTUR PICKS
          UP THE MAIN TITLE FROM TITLE(1)-TITLE(6). THE
          SUBTITLE IS PICKED UP FROM TITLE(7)-TITLE(12). IF THE
          USER WISHES HIS TITLES TO BE CENTERED THEN HE MUST
          STORE HIS CHARACTERS IN TITLE ACCORDINGLY.

  8) IW IS AN INTEGER VARIABLE SPECIFYING THE WIDTH OF THE
        CONTOUR GRAPH IN INCHES (1 IW 9).

  9) IH IS AN INTEGER VARIABLE SPECIFYING THE HEIGHT OF THE
        CONTOUR GRAPH IN INCHES (IH>0).

 10) LTG IS A LOGICAL*1 ARRAY DIMENSIONED LTG(3) WHERE:

     A) LTG(1)=.TRUE. REQUESTS LABELLING OF ALL EXTERIOR CONTOUR
                 SEGMENTS AND THOSE INTERIOR CONTOUR SEGMENTS
                 WHICH REPRESENT A LOCAL MAXIMUM.

        LTG(1)=.FALSE. OMITS LABELLING OPTION.

     B) LTG(2)=.TRUE. REQUESTS TIC MARKS AND CORRESPONDING SCALE
                 VALUES ONE INCH APART ON THE EXTERIOR FRAME OF
                 THE CONTOUR GRAPH.

        LTG(2)=.FALSE. OMITS "TIC" OPTION.

     C) LTG(3)=.TRUE. REQUESTS CONTUR TO SUPERIMPOSE A ONE INCH
                 BY ONE INCH STRAIGHT LINE GRID ON THE CONTOUR
                 GRAPH.

        LTG(3)=.FALSE. OMITS THE GRID OPTION.

C. ERROR MESSAGES

  1) "CONTOUR LINE AT LEVEL (E12.5) WAS TERMINATED AT X=(E12.5),
     Y=(E12.5) BECAUSE IT CONTAINED MORE THAN 1799 POINTS." (THE
     APPROPRIATE VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)

  2) "WIDTH OF CONTOUR GRAPH ILLLEGAL."  (IW.LE.0)

  3) "HEIGHT OF CONTOUR GRAPH ILLEGAL." (IH.LE.0)

  4) "DATA MATRIX HAS ONLY ONE LEVEL."  AFTER SCANNING THE DATA
     MATRIX FOR THE HIGHEST AND LOWEST LEVEL ENTRIES, CONTUR
     FINDS THAT THE MATRIX TO BE CONTOURED CONTAINS THE SAME
     LEVEL VALUE IN ALL ENTRIES.
```

```
      5) "NUMBER OF LEVELS REQUESTED=0."   (NL=0)

      6) "NO GRAPH WILL BE PRODUCED." THIS MESSAGE FOLLOWS 2)-5)
         ABOVE.

      7) " IW PARAMETER GREATER THAN 9. CONTUR WILL SET IW=9."
         PROCESSING CONTINUES WITH IW=9.

4. SUBROUTINES USED

      THE SUBROUTINES DESCRIBED IN "THE PLOTTING PACKAGE FOR NPGS
   IBM 360/67" ARE USED TO DRAW THE CONTOUR GRAPH.  SUBROUTINES
   WHICH FIND THE POINTS TO BE PLOTTED WERE PROVIDED BY
   DR. M.O. DAYHOFF OF THE NATIONAL BIOMEDICAL RESEARCH FOUNDATION,
   SILVER SPRING, MARYLAND.


      SUBROUTINE PLOTT DRAWS THE INTERIOR AND EXTERIOR CONTOUR
   SEGMENTS AND LABELS (IF REQUESTED) THE EXTERIOR CONTOUR
   SEGMENTS.  CONTUR DOES THE LABELLING OF INTERIOR SEGMENTS
   WHICH REPRESENT LOCAL MAXIMA.

5. RESTRICTIONS

   A) INPUT

      1) 1.LE.IW.LE.9

      2) IH.GE.1

      3) WHENEVER NL IS POSITIVE THE DATA MATRIX IS NOT SCANNED FOR
         THE MINIMUM AND MAXIMUM LEVELS; CONSEQUENTLY THE USER IS
         CAUTIONED AGAINST THE POSSIBILITY THAT NO GRAPH WILL BE
         PRODUCED IF

         A) ALL ENTRIES IN THE DATA MATRIX ARE EQUAL

         B) ENTRIES IN THE DATA MATRIX ARE ALL BELOW OR ALL ABOVE
            THE REQUESTED LEVELS.

   B) OUTPUT

      1) ACCURACY IS LIMITED BY THE LINEAR INTERPOLATION PROCESS
         USED IN FINDING THE VALUES OF THE POINTS ALONG CONTOUR
         SEGMENTS. IT IS ALSO LIMITED BY THE RESOLUTION OF THE
         OFFLINE PLOTTER; I.E., .01 INCH IN BOTH THE X AND Y
```

```
          DIRECTIONS.

       2) THE X-SCALE VALUES ALONG THE TIC MARKS ARE 1.0.LE.X.LE.N.
          THE Y-SCALE VALUES ARE 1.0.LE.Y.LE.M.

       3) CNLY UP TO 20 INTERIOR SEGMENTS WHICH REPRESENT
          MAXIMA ARE LABELLED.

    6. STORAGE REQUIREMENTS

         CONTUR AND ALL ITS SUBORDINATE SUBROUTINES REQUIRE 54,570
         BYTES OF CORE.

    7. HARDWARE CONFIGURATION

       A) IBM 360/67EQUIPMENT CONFIGURATION (INCLUDING SPOOLING DISKS,
          ETC.) WITH APPROPRIATE SYSOUT AND SYSIN UNITS.

       B) CALCOMP MODEL 765 PLOTTER

    8. REFERENCES

       A) DAYHOFF,M.O.,"A CONTOUR-MAP PROGRAM FOR X-RAY CRYSTALLOGRAPHY"
          COMMUNICATIONS OF ASSOCIATION FOR COMPUTING MACHINERY,
          OCTOBER 1963

       B) JOHNSON, PATRICIA C.,"PLOTTING PACKAGE FOR NPGS IBM 360/67",
          TECHNICAL NOTE NO. 0211-03, FEBRUARY 1969

       C) HILLEARY, R.R., "J7-NPG-CONTCUR (F-60)", SEPTEMBER 1964.

    9. MATHEMATICAL METHCD

         THE ALGORITHM USED IN FINDING THE CONTOURS IS DEFINED IN
         REFERENCE A).
.........................................................................

      SUBROUTINE CONTUR(AM,M,N,MX,CL,NL,TITLE,IW,IH,LTG)
      REAL*8 TITLE(1)
      REAL*8 WIDTH/'WIDTH'/,HEIGHT/'HEIGHT'/,WHICH
      DIMENSION AM(MX,1),CL(1)
      DIMENSION          REC(900),  X(1800), Y(1800)
      DIMENSION IPT(3,3),INX(8),INY(8)
      COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,
     1            PY,REC,CV,     IPT,INX,INY,DL,RA,THE
      CCMMON /INTFAC/ X,Y
      DIMENSION DITSX(5),DITSY(5)
```

```
      LOGICAL*1 LTG(1),MINUS,LABL                                        CNTR2120
      COMMON/TABL/ TABC(20,6),JC                                         CNTR2130
      COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,DITSDY,IDIR,LABL,MINUS  CNTR2140
      JC=0                                                               CNTR2150
      LABL=LTG(1)                                                        CNTR2160
      CHECK IW PARAMETER                                                 CNTR2170
      WHICH=WIDTH                                                        CNTR2180
      IF(IW) 1,1,2                                                       CNTR2190
    1 WRITE(6,60) WHICH                                                  CNTR2200
   60 FORMAT('0',T7,A8,'OF CONTOUR GRAPH ILLEGAL.')                      CNTR2210
   71 WRITE(6,64)                                                        CNTR2220
   64 FORMAT('0',T7,'NO GRAPH WILL BE PRODUCED.')                        CNTR2230
      RETURN                                                             CNTR2240
      CHECK IF IW IS TOO WIDE                                            CNTR2250
    2 IF(IW-9) 3,3,40                                                    CNTR2260
   40 WRITE(6,61)                                                        CNTR2270
   61 FORMAT('0',T7,'IW PARAMETER GREATER THAN 9. CONTUR WILL SET IW=9.'CNTR2280
     1)                                                                  CNTR2290
      IW=9                                                               CNTR2300
      NOW CHECK IH PARAMETER                                             CNTR2310
    3 IF(IH) 4,4,5                                                       CNTR2320
    4 WHICH=HEIGHT                                                       CNTR2330
      GO TO 1                                                            CNTR2340
    5 DITSDX=(N-1.0)/IW                                                  CNTR2350
      DITSDY=(-1.0+M)/IH                                                 CNTR2360
      XMIN=1.0                                                           CNTR2370
      YMIN=-M                                                            CNTR2380
      SLOPEX=1.0/DITSDX                                                  CNTR2390
      SLOPEY=1.0/DITSDY                                                  CNTR2400
      DITSX(1)=1.0                                                       CNTR2410
      DITSX(4)=1.0                                                       CNTR2420
      DITSX(5)=1.0                                                       CNTR2430
      DITSX(2)=N                                                         CNTR2440
      DITSX(3)=N                                                         CNTR2450
      DITSY(1)=-1.0                                                      CNTR2460
      DITSY(2)=-1.0                                                      CNTR2470
           DITSY(5)=-1.0                                                 CNTR2480
      DITSY(3)=-M                                                        CNTR2490
      DITSY(4)=-M                                                        CNTR2500
      DO 2011 I=1,5                                                      CNTR2510
      DITSX(I)=SLOPEX*(DITSX(I)-XMIN)                                    CNTR2520
 2011 DITSY(I)=SLOPEY*(DITSY(I)-YMIN)                                    CNTR2530
      STARTP=(9.0-IW)/2.0                                                CNTR2540
      CALL PLOTS                                                         CNTR2550
      CALL PLOT(STARTP,0.0,-3)                                           CNTR2560
      CALL LINE(DITSX,DITSY,5,1,1)                                       CNTR2570
      DITSX(1)=DITSX(1)-.5                                               CNTR2580
      DITSX(5)=DITSX(1)                                                  CNTR2590
```

```
      DITSX(4)=DITSX(4)-.5                                            CNTR2600
      DITSX(2)=DITSX(2)+.5                                            CNTR2610
      DITSX(3)=DITSX(3)+.5                                            CNTR2620
      DITSY(1)=DITSY(1)+.5                                            CNTR2630
      DITSY(5)=DITSY(1)                                               CNTR2640
      DITSY(2)=DITSY(2)+.5                                            CNTR2650
      DITSY(3)=DITSY(3)-.5                                            CNTR2660
      DITSY(4)=DITSY(4)-.5                                            CNTR2670
      CALL LINE(DITSX,DITSY,5,1,1)                                    CNTR2680
      SLOPEX=1.0/DITSDX                                               CNTR2690
      SLOPEY=1.0/DITSDY                                               CNTR2700
      IENDX=SLOPEX*N+1                                                CNTR2710
      IENDY=SLOPEY*M+1                                                CNTR2720
      IF(.NOT.LTG(2)) GO TO 34                                        CNTR2730
      DRAW TIC MARKS ON OUTER FRAME                                   CNTR2740
      START ON LEFT EDGE GOING DOWNWARD                               CNTR2750
      IFLAG=0                                                         CNTR2760
      ZINGX=-.1                                                       CNTR2770
      ZINGY=0.0                                                       CNTR2780
      ZX=0.0                                                          CNTR2790
      ZY=-1.0                                                         CNTR2800
      CX=DITSX(1)                                                     CNTR2810
      CY=DITSY(1)-.5                                                  CNTR2820
      IEND=IENDY                                                      CNTR2830
 2222 IFLAG=IFLAG+1                                                   CNTR2840
      DO 2022 I=1,IEND                                                CNTR2850
      CALL PLOT(CX,CY,3)                                              CNTR2860
      CCORDX=CX+ZINGX                                                 CNTR2870
      CCORDY=CY+ZINGY                                                 CNTR2880
      CALL PLOT(COORDX,COORDY,2)                                      CNTR2890
      CX=CX+ZX                                                        CNTR2900
 2022 CY=CY+ZY                                                        CNTR2910
      GO TO (21,22,23,24),IFLAG                                       CNTR2920
      NCW DO THE RIGHT EDGE GOING DOWNWARD                            CNTR2930
   21 ZINGX=.1                                                        CNTR2940
      CX=DITSX(2)                                                     CNTR2950
      CY=DITSY(2)-.5                                                  CNTR2960
      GO TO 2222                                                      CNTR2970
      NCW DO TOP EDGE                                                 CNTR2980
   22 ZINGX=0.0                                                       CNTR2990
      ZINGY=.1                                                        CNTR3000
      ZX=1.0                                                          CNTR3010
      ZY=0.0                                                          CNTR3020
      CX=DITSX(1)+.5                                                  CNTR3030
      CY=DITSY(1)                                                     CNTR3040
      IEND=IENDX                                                      CNTR3050
      GO TO 2222                                                      CNTR3060
      NCW DO THE BOTTOM EDGE                                          CNTR3070
```

```
   23 ZINGY=-.1                                                   CNTR3080
      CX=DITSX(4)+.5                                              CNTR3090
      CY=DITSY(4)                                                 CNTR3100
      ZINGY=-.1                                                   CNTR3110
      GO TO 2222                                                  CNTR3120
      NOW LABEL TIC MARKS                                         CNTR3130
      DO X-DIRECTION FIRST, TOP EDGE                              CNTR3140
      POSITION PEN                                                CNTR3150
   24 DELTAX=DITSDX                                               CNTR3160
      IFLAG=0                                                     CNTR3170
      ZX=1.0                                                      CNTR3180
      ZY=0.0                                                      CNTR3190
      CX=DITSX(1)+.35                                             CNTR3200
      CY=DITSY(1)+.12                                             CNTR3210
 3033 IFLAG=IFLAG+1                                               CNTR3220
      XZERO=1.0                                                   CNTR3230
      DO 3333 I=1,IEND                                            CNTR3240
      CALL NUMBER(CX,CY,.07,XZERO,0.0,1)                          CNTR3250
      CX=CX+ZX                                                    CNTR3260
      CY=CY+ZY                                                    CNTR3270
 3333 XZERO=XZERO+DELTAX                                          CNTR3280
      GO TO (31,32,33,34),IFLAG                                   CNTR3290
      LABEL BOTTOM EDGE TIC MARKS                                 CNTR3300
   31 CX=DITSX(4)+.35                                             CNTR3310
      CY=DITSY(4)-.19                                             CNTR3320
      GO TO 3033                                                  CNTR3330
      LABEL LEFT EDGE OF TIC MARKS                                CNTR3340
   32 CX=DITSX(4)-.4                                              CNTR3350
      CY=DITSY(4)+.46                                             CNTR3360
      DELTAX=DITSDY                                               CNTR3370
      IEND=IENDY                                                  CNTR3380
      ZX=0.0                                                      CNTR3390
      ZY=1.0                                                      CNTR3400
      GO TO 3033                                                  CNTR3410
      NOW LABEL RIGHT EDGE TIC MARKS                              CNTR3420
   33 CX=DITSX(3)+.12                                             CNTR3430
      CY=DITSY(3)+.46                                             CNTR3440
      GO TO 3033                                                  CNTR3450
      CHECK IF GRID DESIRED                                       CNTR3460
   34 IF(.NOT.LTG(3)) GO TO 35                                    CNTR3470
      DRAW INCH BY INCH GRID                                      CNTR3480
      IEND=IENDX-2                                                CNTR3490
      POSITION PEN                                                CNTR3500
      IFLAG=0                                                     CNTR3510
      CX=DITSX(1)+.5                                              CNTR3520
      CY=DITSY(1)-.5                                              CNTR3530
      COORDX=0.0                                                  CNTR3540
      COORDY=-IH                                                  CNTR3550
```

```
      DX=1.0                                                            CNTR3560
      DY=0.0                                                            CNTR3570
 4044 DO 4444  I=1,IEND                                                 CNTR3580
      CX=CX+DX                                                          CNTR3590
      CY=CY+DY                                                          CNTR3600
      CALL PLOT (CX,CY,3)                                               CNTR3610
      ZX=CX+CCORDX                                                      CNTR3620
      ZY=CY+COORDY                                                      CNTR3630
 4444 CALL PLOT(ZX,ZY,2)                                                CNTR3640
      IF(IFLAG) 35,42,35                                                CNTR3650
   42 IFLAG=1                                                           CNTR3660
      IEND=IENDY-2                                                      CNTR3670
      CY=DITSY(4)+.5                                                    CNTR3680
      CX=DITSX(4)+.5                                                    CNTR3690
      CCORDX=IW                                                         CNTR3700
      CCORDY=0.0                                                        CNTR3710
      DX=0.0                                                            CNTR3720
      DY=1.0                                                            CNTR3730
      GO TO 4044                                                        CNTR3740
   35 CCNTINUE                                                          CNTR3750
      NLEV=NL                                                           CNTR3760
      CHECK IF CONTUR IS TC  COMPUTE LEVELS                             CNTR3770
      IF(NLEV) 6,7,11                                                   CNTR3780
      NL NEGATIVE  MEANS CONTCUR MUST CCMPUTE LEVELS                    CNTR3790
      SCAN MATRIX FOR LOWEST AND HIGHEST LEVELS                         CNTR3800
    6 NLEV=-NLEV                                                        CNTR3810
      FMIN=AM(1,1)                                                      CNTR3820
      FMAX=FMIN                                                         CNTR3830
      DC 9 I=1,M                                                        CNTR3840
      DO 9 J=1,N                                                        CNTR3850
      IF(AM(I,J).LT.FMIN) FMIN=AM(I,J)                                  CNTR3860
      IF(AM(I,J).GT.FMAX) FMAX=AM(I,J)                                  CNTR3870
    9 CONTINUE                                                          CNTR3880
      CHECK IF MIN AND MAX ARE EQUAL                                    CNTR3890
      IF(FMIN.GE.FMAX) GO TO 300                                        CNTR3900
      DELTAL=(FMAX-FMIN)/(NLEV-1)                                       CNTR3910
      SET UP CL ARRAY                                                   CNTR3920
      DO 10 I=1,NLEV                                                    CNTR3930
   10 CL(I)=FMIN+(I-1)*DELTAL                                           CNTR3940
   11 DO 20 I=1,NLEV                                                    CNTR3950
   20 CALL SCAN(AM,M,N,MX,CL(I))                                        CNTR3960
      IF(.NOT.LABL) GO TO 778                                           CNTR3970
      IF(JC.EQ.0) GO TO 778                                             CNTR3980
      DO 777 I=1,JC                                                     CNTR3990
      COORDX=TABC(I,4)                                                  CNTR4000
      COORDY=TABC(I,5)                                                  CNTR4010
      CLEV=TABC(I,6)                                                    CNTR4020
      CALL NUMBER(COORDX,COORDY,.07,CLEV,0.0,1)                         CNTR4030
```

```
777 CONTINUE                                                        CNTR4040
778 CALL SYMBOL(-STARTP,IH+1.0,.21,TITLE(7),0.0,48)                 CNTR4050
    CALL SYMBOL(-STARTP,IH+1.5,.21,TITLE(1),0.0,48)                 CNTR4060
    CALL PLOT(-STARTP,IH+5.0,-3)                                    CNTR4070
    CALL PLOTE                                                      CNTR4080
    RETURN                                                          CNTR4090
300 WRITE(6,62) FMIN                                                CNTR4100
 62 FORMAT('0',T7,'DATA MATRIX HAS ONLY ONE LEVEL=',E15.3)          CNTR4110
    GO TO 71                                                        CNTR4120
  7 WRITE(6,63)                                                     CNTR4130
 63 FORMAT('0',T7,'NUMBER OF LEVELS REQUESTED=0.')                  CNTR4140
    GO TO 71                                                        CNTR4150
    END                                                             CNTR4160


    SUBROUTINE SCAN(AM,M,N,MX,CL)                                   CNTR4170
THIS PROGRAM IS WRITTEN BY M.O.DAYHOFF                              CNTR4180
    DIMENSION AM(MX,1 ),REC(900),   X(1800),  Y(1800)               CNTR4190
    DIMENSION IPT(3,3),INX(8),INY(8)                                CNTR4200
    COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,NQ,JT,      CNTR4210
   1                PY,REC,CV,     IPT,INX,INY,DL,RA,THE            CNTR4220
    COMMON /INTFAC/ X,Y                                             CNTR4230
    LOGICAL *1 LABL,MINUS                                           CNTR4240
    COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,DITSDY,IDIR,LABL,MINUS CNTR4250
    D=0.                                                            CNTR4260
    R=1.                                                            CNTR4270
    TH = 1.570796                                                   CNTR4280
    NP=0                                                            CNTR4290
    DL=D                                                            CNTR4300
    RA=R                                                            CNTR4310
    THE=TH                                                          CNTR4320
    MT=N                                                            CNTR4330
    NT=M                                                            CNTR4340
    CV=CL                                                           CNTR4350
    IF(IZW-120631) 1,3,1                                            CNTR4360
  1 IPT(1,1)=8                                                      CNTR4370
    IPT(1,2)=1                                                      CNTR4380
    IPT(1,3)=2                                                      CNTR4390
    IPT(2,1)=7                                                      CNTR4400
    IPT(2,3)=3                                                      CNTR4410
    IPT(3,1)=6                                                      CNTR4420
    IPT(3,2)=5                                                      CNTR4430
    IPT(3,3)=4                                                      CNTR4440
    INX(1)=-1                                                       CNTR4450
    INX(2)=-1                                                       CNTR4460
    INX(3)=0                                                        CNTR4470
    INX(4)=1                                                        CNTR4480
    INX(5)=1                                                        CNTR4490
```

```
      INX(6)=1                                                          CNTR4500
      INX(7)=0                                                          CNTR4510
      INX(8)=-1                                                         CNTR4520
      INY(1)=0                                                          CNTR4530
      INY(2)=1                                                          CNTR4540
      INY(3)=+1                                                         CNTR4550
      INY(4)=+1                                                         CNTR4560
      INY(5)=0                                                          CNTR4570
      INY(6)=-1                                                         CNTR4580
      INY(7)=-1                                                         CNTR4590
      INY(8)=-1                                                         CNTR4600
      IZW=120631                                                        CNTR4610
    3 XT=MT                                                             CNTR4620
      DO 58 J=1,900                                                     CNTR4630
   58 REC(J)=0                                                          CNTR4640
      ISS=0                                                             CNTR4650
    2 MT1=MT-1                                                          CNTR4660
      IDIR=1                                                            CNTR4670
      DO 110 I=1,MT1                                                    CNTR4680
      IF(AM(1,I)-CV) 55,110,110                                         CNTR4690
   55 IF(AM(1,I+1)-CV) 110,57,57                                        CNTR4700
   57 IX=I+1                                                            CNTR4710
      IY=1                                                              CNTR4720
      IDX=-1                                                            CNTR4730
      IDY=0                                                             CNTR4740
      CALL TRACE (AM,MX)                                                CNTR4750
  110 CONTINUE                                                          CNTR4760
      NT1=NT-1                                                          CNTR4770
      IDIR=2                                                            CNTR4780
      DO 20 I=1,NT1                                                     CNTR4790
      IF(AM(I,MT)-CV) 15,20,20                                          CNTR4800
   15 IF(AM(I+1,MT)-CV) 20,17,17                                        CNTR4810
   17 IX=MT                                                             CNTR4820
      IY=I+1                                                            CNTR4830
      IDX=0                                                             CNTR4840
      IDY=-1                                                            CNTR4850
      CALL TRACE (AM,MX)                                                CNTR4860
   20 CONTINUE                                                          CNTR4870
      IDIR=3                                                            CNTR4880
   22 DO 30 I=1,MT1                                                     CNTR4890
      MT2=MT+1-I                                                        CNTR4900
      IF(AM(NT,MT2)-CV) 25,30,30                                        CNTR4910
   25 IF(AM(NT,MT2-1)-CV) 30,27,27                                      CNTR4920
   27 IX=MT2-1                                                          CNTR4930
      IY=NT                                                             CNTR4940
      IDX=1                                                             CNTR4950
      IDY=0                                                             CNTR4960
      CALL TRACE (AM,MX)                                                CNTR4970
```

```
   30 CONTINUE                                                          CNTR4980
      IDIR=4                                                            CNTR4990
      DO 40  I=1,NT1                                                    CNTR5000
      NT2=NT+1-I                                                        CNTR5010
      IF(AM(NT2,1)-CV) 35,40,40                                         CNTR5020
   35 IF(AM(NT2-1,1)-CV) 40,37,37                                       CNTR5030
   37 IX=1                                                              CNTR5040
      IY=NT2-1                                                          CNTR5050
      IDX=0                                                             CNTR5060
      IDY=1                                                             CNTR5070
      CALL TRACE (AM,MX)                                                CNTR5080
   40 CONTINUE                                                          CNTR5090
      IDIR=5                                                            CNTR5100
      ISS=1                                                             CNTR5110
      NT1=NT-1                                                          CNTR5120
      MT1=MT-1                                                          CNTR5130
      DO 10  J=2,NT1                                                    CNTR5140
      DO 10  I=1,MT1                                                    CNTR5150
      IF(AM(J,I)-CV)5,10,10                                             CNTR5160
    5 IF(AM(J,I+1)-CV) 10,7,7                                           CNTR5170
    7 COM=100*(I+1)+J                                                   CNTR5180
      IF (NP) 12,11,12                                                  CNTR5190
   12 DO 9  ID= 1,NP                                                    CNTR5200
      IF (REC(ID)-COM) 9,10,9                                           CNTR5210
    9 CONTINUE                                                          CNTR5220
   11 IX= I+1                                                           CNTR5230
      IY=J                                                              CNTR5240
      IDX=-1                                                            CNTR5250
      IDY=0                                                             CNTR5260
      CALL TRACE (AM,MX)                                                CNTR5270
   10 CONTINUE                                                          CNTR5280
      RETURN                                                            CNTR5290
      END                                                               CNTR5300

      SUBROUTINE TRACE (AM,MY)                                          CNTR5310
      DIMENSION AM(MY,1 ),REC(900),  X(1800), Y(1800)                   CNTR5320
      DIMENSION IPT(3,3), INX(8),INY(8)                                 CNTR5330
      COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,        CNTR5340
     1                PY,REC,CV,     IPT,INX,INY,DL,RA,THE              CNTR5350
      COMMON /INTFAC/ X,Y                                               CNTR5360
      PY=0.0                                                            CNTR5370
      RC=  COS (THE)*RA                                                 CNTR5380
      RS=  SIN (THE)*RA                                                 CNTR5390
  501 JT=0                                                              CNTR5400
      N=0                                                               CNTR5410
      IXC=IX                                                            CNTR5420
      IYO=IY                                                            CNTR5430
```

```
      ISX=IDX+2                                                         CNTR5440
      ISY=IDY+2                                                         CNTR5450
      IS=IPT(ISX,ISY)                                                   CNTR5460
      JTB=0                                                             CNTR5470
      ISO=IS                                                            CNTR5480
      IF(ISO-8)18,18,17                                                 CNTR5490
   17 ISO=ISO-8                                                         CNTR5500
   18 IT=0                                                              CNTR5510
    5 CONTINUE                                                          CNTR5520
      CALL CALC   (AM,MY)                                               CNTR5530
      NZ=N                                                              CNTR5540
      N=NZ                                                              CNTR5550
      IF (IT+JT-1) 49,49,47                                             CNTR5560
   47 XS=X(N-1)                                                         CNTR5570
      YS=Y(N-1)                                                         CNTR5580
      X(N-1)=X(N)                                                       CNTR5590
      Y(N-1)=Y(N)                                                       CNTR5600
      X(N)=XS                                                           CNTR5610
      Y(N)=YS                                                           CNTR5620
   49 IS=IS+1                                                           CNTR5630
      JT=IT                                                             CNTR5640
    9 IF (IS-9) 8,7,7                                                   CNTR5650
    7 IS=IS-8                                                           CNTR5660
    8 IDX=INX(IS)                                                       CNTR5670
      IDY=INY(IS)                                                       CNTR5680
      IX2=IX+IDX                                                        CNTR5690
      IY2=IY+IDY                                                        CNTR5700
      JTB=JTB+1                                                         CNTR5710
      IF (JTB-1799) 51,51,308                                           CNTR5720
  308 PRINT                 103,CV,X(N),Y(N)                            CNTR5730
  103 FORMAT(1H0,23HA CONTOUR LINE AT LEVEL,E12.5,21H WAS TERMINATED AT CNTR5740
     1X=,E12.5,3H Y=,E12.5/                                             CNTR5750
     2 48H BECAUSE IT CONTAINED MORE THAN 1799 PLOT POINTS   )          CNTR5760
      RETURN                                                            CNTR5770
                                                                        CNTR5780
    SHOULD TEST HERE FOR MAXIMUM NUMBER OF PLOTTABLE POINTS IN SEGMENT. CNTR5790
   51 CONTINUE                                                          CNTR5800
      IF (ISS) 10,10,20                                                 CNTR5810
   20 IF(IX-IXO) 12,21,12                                               CNTR5820
   21 IF(IY-IYO) 12,22,12                                               CNTR5830
   22 IF(IS-ISO) 12,23,12                                               CNTR5840
   23 CONTINUE                                                          CNTR5850
      CALL CALC   (AM,MY)                                               CNTR5860
      GO TO 73                                                          CNTR5870
   10 IF(IX2) 13,50,13                                                  CNTR5880
   13 IF (IX2-MT) 19,19,50                                              CNTR5890
   19 IF (IY2) 11,50,11                                                 CNTR5900
   11 IF (IY2-NT) 12,12,50                                              CNTR5910
```

```
   12 IF(CV-AM(IY2,IX2)) 206,206,5                                  CNTR5920
  206 IF (IDX**2+IDY**2-1) 213,6,213                                CNTR5930
  213 DCP=(AM(IY,IX)+AM(IY,IX2)+AM(IY2,IX)+AM(IY2,IX2))/4.0          CNTR5940
      IF (DCP-CV) 5,217,217                                         CNTR5950
  217 IF (INX(IS-1)) 214,215,214                                    CNTR5960
  214 IX=IX+IDX                                                     CNTR5970
      IDX=-IDX                                                      CNTR5980
      PY=2.0                                                        CNTR5990
      CALL CALC  (AM,MY)                                            CNTR6000
      IX=IX+IDX                                                     CNTR6010
      GO TO 6                                                       CNTR6020
  215 IY=IY+IDY                                                     CNTR6030
      IDY=-IDY                                                      CNTR6040
      PY=2.0                                                        CNTR6050
      CALL CALC  (AM,MY)                                            CNTR6060
      IY=IY+IDY                                                     CNTR6070
    6 IF(AM(IY,IX-1)-CV) 306,16,16                                  CNTR6080
  306 NP=NP+1                                                       CNTR6090
      REC(NP)=100*IX+IY                                             CNTR6100
   16 IS=IS+5                                                       CNTR6110
      IX=IX2                                                        CNTR6120
      IY=IY2                                                        CNTR6130
      GO TO 9                                                       CNTR6140
   50 XT=MT                                                         CNTR6150
      IF(AM(IY,IX-1)-CV) 307,73,73                                  CNTR6160
  307 NP=NP+1                                                       CNTR6170
      REC(NP)=100*IX+IY                                             CNTR6180
   73 DO 74 I=1,N                                                   CNTR6190
      X(I)=X(I)+RC*Y(I)                                             CNTR6200
   74 Y(I)=RS*Y(I)                                                  CNTR6210
      CALL PLOTT(N,CV)                                              CNTR6220
      RETURN                                                        CNTR6230
      END                                                           CNTR6240

      SUBROUTINE CALC(AM,MY)                                        CNTR6250
      DIMENSION AM(MY,1 ),REC(900),  X(1800), Y(1800)               CNTR6260
      DIMENSION IPT(3,3),INX(8),INY(8)                              CNTR6270
      COMMON /DAYHOF/ MT,NT,NI,IX,IY,IDX,IDY,ISS,IT,IV,NP,N ,JT,    CNTR6280
     1                PY,REC,CV,    IPT,INX,INY,DL,RA,THE           CNTR6290
      COMMON /INTFAC/ X,Y                                           CNTR6300
      IT=0                                                          CNTR6310
      N=N+1                                                         CNTR6320
      IF (IDX**2 + IDY**2 -1) 20,1,20                               CNTR6330
    1 IF (IDX) 10,2,10                                              CNTR6340
    2 X(N)=IX                                                       CNTR6350
      Z=IY                                                          CNTR6360
      IY2=IY+IDY                                                    CNTR6370
```

```
      DY=IDY                                                            CNTR6380
   41 Y(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY2,IX)))*DY+Z                 CNTR6390
      RETURN                                                            CNTR6400
   10 Y(N)=IY                                                           CNTR6410
      W=IX                                                              CNTR6420
      DX=IDX                                                            CNTR6430
      IX2=IX+IDX                                                        CNTR6440
   44 X(N)=((AM(IY,IX)-CV)/(AM(IY,IX)-AM(IY,IX2)))*DX+W                 CNTR6450
      RETURN                                                            CNTR6460
   20 IX2=IX+IDX                                                        CNTR6470
      IY2=IY+IDY                                                        CNTR6480
      W=IX                                                              CNTR6490
      Z=IY                                                              CNTR6500
      DX=IDX                                                            CNTR6510
      DY=IDY                                                            CNTR6520
      DCP=(AM(IY,IX)+AM(IY,IX2)+AM(IY2,IX)+AM(IY2,IX2))/4.0             CNTR6530
      IF (PY-2.0) 24,21,24                                              CNTR6540
   24 IF (DCP-CV) 21,21,25                                              CNTR6550
   21 AL=AM(IY,IX)-DCP                                                  CNTR6560
   23 V=.5*(AL+DCP -CV)/AL                                              CNTR6570
   27 X(N)=V*DX+W                                                       CNTR6580
      Y(N)=V*DY+Z                                                       CNTR6590
      PY=0.0                                                            CNTR66C0
      RETURN                                                            CNTR6610
   25 IT=1                                                              CNTR6620
      AL=AM(IY2,IX2)-DCP                                                CNTR6630
   33 V=.5*(AL+DCP-CV)/AL                                               CNTR6640
   28 X(N)=-V*DX+W + DX                                                 CNTR6650
      Y(N)=-V*DY+Z + DY                                                 CNTR6660
      Y(N)=-V*DY+Z + DY                                                 CNTR6670
      RETURN                                                            CNTR6680
      END                                                               CNTR6690


      SUBROUTINE PLOTT(NP,CV)                                           CNTR67C0
      CCMMON/INTFAC/X(1800),Y(1800)                                     CNTR6710
      LOGICAL*1 MINUS,LABL                                              CNTR6720
      COMMON/TABL/ TABC(20,6),JC                                        CNTR6730
      COMMON/DITS/XMIN,YMIN,SLOPEX,SLOPEY,DITSDX,DITSDY,IDIR,LABL,MINUS CNTR6740
      SCALE PCINTS FOR PLOT ROUTINE                                     CNTR6750
      DC 100 I=1,NP                                                     CNTR6760
      X(I)=SLOPEX*(X(I)-XMIN)                                           CNTR6770
  100 Y(I)=SLCPEY*(-Y(I)-YMIN)                                          CNTR6780
      CALL LINE(X,Y,NP,1,1)                                             CNTR6790
      IF(.NOT.LABL) RETURN                                              CNTR6800
      SHCULD ADJUSTMENT CF PEN LOCATION BE MADE FOR LABELLING CURVE?    CNTR6810
      DIR=0.0                                                           CNTR6820
      GC TO (1,2,3,4,6), IDIR                                           CNTR6830
```

```
    1 DIR=90.                                                           CNTR6840
    2 CCORDX=X(1 )                                                      CNTR6850
      COORDY=Y(1 )                                                      CNTR6860
    5 CALL NUMBER(COORDX,COORDY,.07,CV,DIR,1)                           CNTR6870
      RETURN                                                            CNTR6880
      MOVE PEN DOWN ONE HALF INCH                                       CNTR6890
    3 DIR=90.                                                           CNTR6900
      CCORDX=X(1 )                                                      CNTR6910
      COORDY=Y(1 )-.3                                                   CNTR6920
      GC TO 5                                                           CNTR6930
      MOVE PEN TO THE LEFT                                              CNTR6940
    4 COORDX=X(1 )-.3                                                   CNTR6950
      CCORDY=Y(1 )                                                      CNTR6960
      GO TO 5                                                           CNTR6970
      SEARCH FOR XMAX,XMIN,YMAX,YMIN,AND SAVE YMINX                     CNTR6980
    6 XMAX=X(1)                                                         CNTR6990
      SMIN=XMAX                                                         CNTR7000
      YMINX=Y(1)                                                        CNTR7010
      YMAX=YMINX                                                        CNTR7020
      VMIN=YMINX                                                        CNTR7030
      DO 200 I=2,NP                                                     CNTR7040
      IF(X(I).GT.XMAX) XMAX=X(I)                                        CNTR7050
      IF(Y(I).LT.VMIN) VMIN=Y(I)                                        CNTR7060
      IF(Y(I).GT.YMAX) YMAX=Y(I)                                        CNTR7070
      IF(X(I).GE.SMIN) GO TO 200                                        CNTR7080
      SMIN=X(I)                                                         CNTR7090
      YMINX=Y(I)                                                        CNTR7100
  200 CONTINUE                                                          CNTR7110
      JC=NUMBER OF ENTRIES IN TABC                                      CNTR7120
      IF(JC) 400,500,400                                                CNTR7130
      SEARCH TABLE TO SEE IF THIS IS INTERIOR TC ANCTHER INTERIOR SEGMENCNTR7140
  400 DO 900 I=1,JC                                                     CNTR7150
      IF(XMAX.LT.TABC(I,1).AND.YMAX.LT.TABC(I,2).AND.VMIN.GT.TABC(I,3). CNTR7160
     1AND.SMIN.GT.TABC(I,4)) GO TO 700                                  CNTR7170
  900 CCNTINUE                                                          CNTR7180
      DID NOT FIND THIS CONTOUR TO BE INTERIOR TC ANOTHER               CNTR7190
      CHECK IF EXTERIOR                                                 CNTR7200
      DO 1000 I=1,JC                                                    CNTR7210
      IF(XMAX.GT.TABC(I,1).AND.YMAX.GT.TABC(I,2).AND.VMIN.LT.TABC(I,3). CNTR7220
     1AND.SMIN.LT.TABC(I,4)) GO TO 800                                  CNTR7230
 1000 CCNTINUE                                                          CNTR7240
      THIS CONTOUR SEGMENT WAS NEITHER INTERIOR NCR EXTERICR TC ANOTHER CNTR7250
  500 IF (JC.EQ.20) RETURN                                              CNTR7260
      JC=JC+1                                                           CNTR7270
      MC=JC                                                             CNTR7280
  600 TABC(MC,1)=XMAX                                                   CNTR7290
      TABC(MC,2)=YMAX                                                   CNTR7300
      TABC(MC,3)=VMIN                                                   CNTR7310
```

```
      TABC(MC,4)=SMIN                                                   CNTR7320
      TABC(MC,5)=YMINX                                                  CNTR7330
      TABC(MC,6)=CV                                                     CNTR7340
      RETURN                                                            CNTR7350
C     CHECK IF THIS INTERIOR ONE IS OF HIGHER LEVEL                     CNTR7360
  700 IF(CV.LE.TABC(I,6) ) RETURN                                       CNTR7370
 2000 MC=I                                                              CNTR7380
      GO TO 600                                                         CNTR7390
C     CHECK IF LEVEL OF THIS EXTERIOR ONE IS HIGHER                     CNTR7400
  800 IF(CV.LT.TABC(I,6)) RETURN                                        CNTR7410
      GO TO 2000                                                        CNTR7420
      END                                                               CNTR7430
```

APPENDIX B

```
*************************************************************************
*                           SUBPROGRAMS                                 *
*                    AND RELATED SUBROUTINES                            *
*                                                                       *
*************************************************************************

*************************************************************************
                         PROGRAM FOR INTRPL
      DIMENSION BB(101,20),TH(13),X(101),Y(101),U(60),V(60)
  100 FORMAT (4I10,2F10.5)
  101 FORMAT (F10.5)
  102 FORMAT (T10,I5,2F10.5)
  103 FORMAT (8F10.5)
  105 FORMAT (T10,I5,F10.5)
      READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
      FNP=FLOAT(NP)
      DR=2*RMAX/(FNP-1)
      L=NP-(NP-1)/4
      L2=L/2
      LW=NP-L/2
      N=NP-L
      DO 10 J=1,NT
      READ(5,101) TH(J)
      READ(5,103,END=10)(BB(I,J),I=1,NP)
   10 CONTINUE
   11 DO 110 J=1,NT
      DO 30 I=1,NP
   12 K=I-1
      IF(I.GT.L2) GO TO 15
      Y(I)=BB(I,J)
      X(I)=-RMAX+K*DR
      GO TO 30
5     IF(I.GT.LW) GO TO 20
      LL=I-L2
      U(LL)=-RMAX+K*DR
      GO TO 30
   20 KK=I-N
      Y(KK)=BB(I,J)
      X(KK)=-RMAX +K*DR
```

```
0     CONTINUE
      WRITE(6,103)(X(I),I=1,L)
      WRITE(6,103)(Y(I),I=1,L)
      WRITE(6,103)(U(I),I=1,N)
      CALL INTRPL(L,X,Y,N,U,V)
      WRITE(6,103)(V(I),I=1,N)
*****TO PRINT THE OUTPUT (I.E. Y(1) TO Y(36, V(1), TO V(25),
      Y(37)  TO Y(76)  ), IN A TOTAL 8F10.5 FORMAT, STORE THE
*****TWO VECTORS IN BB(I,J)
      DO 70 I=1,NP
      LL=I-L2
      KK=I-N
      IF(I.GT.L2) GO TO 42
      BB(I,J)=Y(I)
      GO TO 70
   42 IF(I.GT.LW) GO TO 50
      BB(I,J)=V(LL)
      GO TO 70
   50 BB(I,J)=Y(KK)
   70 CONTINUE
      WRITE(6,103) TH(J)
      WRITE(6,103)(BB(I,J),I=1,NP)
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=1,NP)
10    CONTINUE
      STOP
      END
**********************************************************************

**********************************************************************
                        PROGRAM FOR INTRPL (LINEAR)
      DIMENSION BB(101,20),TH(13),X(101),Y(101),U(60),V(60)
  100 FORMAT (4I10,2F10.5)
  101 FORMAT (F10.5)
  102 FORMAT (T10,I5,2F10.5)
  103 FORMAT (8F10.5)
  105 FORMAT (T10,I5,F10.5)
      READ(5,100) MODE,NP,NT,KSYM,RMAX,FILTER
      FNP=FLOAT(NP)
      DR=2*RMAX/(FNP-1)
      L=NP-(NP-1)/4
      L2=L/2
      LW=NP-L/2
      N=NP-L
      N2N=2
      DO 10 J=1,NT
      READ(5,101) TH(J)
```

```
      READ(5,103,END=10)(BB(I,J),I=1,NP)
   10 CONTINUE
   11 DC 110 J=1,NT
      LW1=LW+1
      X(1)=-RMAX+(L2-1)*DR
      X(2)=-RMAX+(L2+N)*DR
      Y(1)=BB(L2,J)
      Y(2)=BB(LW1,J)
      DC 20 I=1,N
      U(I)=-RMAX+(L2-1+I)*DR
   20 CCNTINUE
      WRITE(6,103)X(1),X(2)
      WRITE(6,103)Y(1),Y(2)
      WRITE(6,103)(U(I),I=1,N)
      CALL INTRPL(N2N,X,Y,N,U,V)
      WRITE(6,103)(V(I),I=1,N)
*****TO PRINT THE OUTPUT (I.E. Y(1) TO Y(36, V(1), TO V(25),
      Y(37)  TO Y(76)   ), IN A TOTAL 8F10.5 FORMAT, STORE THE
*****TWO VECTORS IN BB(I,J)
      DC 30 I=1,N
      KBB=L2+I
      BB(KBB,J)=V(I)
   3C CCNTINUE
      WRITE(6,103) TH(J)
      WRITE(6,103)(BB(I,J),I=1,NP)
      WRITE(7,103) TH(J)
      WRITE(7,103)(BB(I,J),I=1,NP)
10    CONTINUE
      STOP
      END
***********************************************************************

***********************************************************************

.......................................................................  INTR0010
                                                                         INTR0020

      SUBROUTINE INTRPL        (CATEGORY E2)                             INTR0030
                                                                         INTR0040
      1. IDENTIFICATION:                                                 INTR0050
                                                                         INTR0060
         A. NAME: INTERPOLATICN OF A SINGLE VALUEC FUNCTION              INTR0070
                  BASED ON LOCAL PROCEDURES                              INTR0080
                                                                         INTRCC90
         B. PROGRAMMER:  HIROSHI AKIMA                                   INTR0100
```

```
    C. IMPLEMENTER: MICHAEL CORCORAN

    D. DATE: MARCH, 1973

 2. PURPOSE:

    A. THE INTRPL SUBROUTINE INTERPOLATES, FROM VALUES OF THE


       FUNCTION GIVEN AS ORDINATES OF INPUT DATA POINTS IN AN
       X-Y PLANE AND FOR A GIVEN SET OF X VALUES (ABSCISSAS OF
       DESIRED POINTS), THE VALUES OF A SINGLE VALUED FUNCTION
       Y = Y(X).

 3. USAGE:

    A. CALLING STATEMENT:

       CALL INTRPL(L,X,Y,N,U,V)

       WHERE THE INPUT PARAMETERS ARE:

       1) L  -  THE NUMBER OF INPUT DATA POINTS (MUST BE 2 OR MORE)

       2) X  -  AN ARRAY OF DIMENSION L STORING THE X VALUES
                (ABSCISSAS) OF THE INPUT DATA POINTS IN ASCENDING
                ORDER....X(I+1) > X(I)     (TYPE REAL*4)

       3) Y  -  AN ARRAY OF DIMENSION L STORING THE Y VALUES
          (ORDINATES) OF THE INPUT DATA POINTS    (TYPE REAL*4)

       4) N  -  THE NUMBER OF POINTS AT WHICH INTERPOLATION OF THE
                Y VALUE (ORDINATE) IS DESIRED  (MUST BE ONE OR MORE)

       5) U  -  THE ARRAY OF DIMENSION N STORING THE X VALUES
                (ABSCISSAS) OF DESIRED POINTS   (TYPE REAL*4)


       AND WHERE THE OUTPUT PARAMETER IS

       6) V  -  THE ARRAY OF DIMENSION N WHERE THE INTERPOLATED
                Y VALUES (ORDINATES) ARE TO BE PLACED

    B. ERROR MESSAGES:

       1)  "***   L = 1 OR LESS.
               L =(I7)           N =(I7)
```

```
         ERROR DETECTED IN ROUTINE    INTRPL"  (THE APPROPRIATE
         VALUES ARE PRINTED WHERE FORMATS ARE INDICATED)

      2) "***   N = 0 OR LESS.
             L =(I7)             N =(I7)
         ERROR DETECTED IN ROUTINE    INTRPL"

      3) "***   IDENTICAL X VALUES.
             I =(I7)             X(I) =(E12.3)
             L =(I7)             N =(I7)
         ERROR DETECTED IN ROUTINE    INTRPL"   ( THE VALUES IN
         THE X ARRAY MUST BE IN STRICT ASCENDING SEQUENCE.)

      4) "***   X VALUES OUT OF SEQUENCE.
             I =(I7)             X(I) =(E12.3)
             L =(I7)             I =(I7)
         ERROR DETECTED IN ROUTINE    INTRPL"  ( X(I) < X(I-1) FOR
                                                 SOME I BETWEEN
                                                 2 AND L. )

4. MODE OF ARITHMETIC:

   SINGLE PRECISION

5. REMARKS:

   A. WHEN THE FUNCTION TO BE INTERPOLATED REPRESENTS A PERIODIC


      FUNCTION AND A SET OF L DATA POINTS COVERS A WHOLE PERIOD,
      TWO ADDITIONAL DATA POINTS SHOULD BE ADDED AT EACH END AND
      A SET OF L+4 DATA POINTS SHOULD BE GIVEN AS THE INPUT DATA
      POINTS TO THIS SUBROUTINE.

   B. CORE REQUIREMENT FOR INTRPL:  2968 BYTES.

   C. NO SUBROUTINES OR FUNCTION SUBPROGRAMS ARE REQUIRED.

   D. FOR THE CONVENIENCE OF THE NPS USER, THE ORIGINAL FORTRAN
      PROGRAM WAS MODIFIED SLIGHTLY. AN UNNECESSARY INPUT
      PARAMETER - IU, WHICH DESIGNATED THE OUPUT DEVICE NUMBER
      FOR ERROR MESSAGES FROM INTRPL, WAS ELIMINATED FROM THE
      PARAMETER LIST, AND THE FORTRAN CODE WAS MODIFIED TO CHANNEL
      ALL ERROR MESSAGES TO THE LINE PRINTER AUTOMATICALLY.

6. METHOD:

      THIS ROUTINE IS DEVISED IN SUCH A WAY THAT A CURVE DWAWN
```

```
      THROUGH BOTH THE GIVEN AND INTERPOLATED POINTS WILL APPEAR
      SMOOTH AND NATURAL, FREE OF UNNATURAL WIGGLES.  IT IS BASED
      ON A PIECEWISE FUNCTION COMPOSED OF A SET OF POLYNOMIALS,
      EACH OF DEGREE THREE, AT MOST, AND APPLICABLE TO SUCCESSIVE
      INTERVALS OF THE GIVEN POINTS.  IN THIS METHOD, THE SLOPE OF
      THE CURVE IS DETERMINED AT EACH GIVEN POINT LOCALLY, AND
      EACH POLYNOMIAL REPRESENTING A PORTION OF THE CURVE BETWEEN
      A PAIR OF GIVEN POINTS IS DETERMINED BY THE COORDINATES OF
      AND THE SLOPES AT THE POINTS.  COMPARISON INDICATES THAT THE
      CURVE OBTAINED BY THIS METHOD IS CLOSER TO A MANUALLY DRAWN
      CURVE THAN THOSE DRAWN BY OTHER MATHEMATICAL METHODS...

      A DETAILED EXPLANATION OF THE METHOD CAN BE FOUND IN THE
      OCTOBER 1970 ISSUE, JOURNAL OF THE ACM, PAGE 589, ENTITLED:
      "A NEW METHOD OF INTERPOLATION AND SMOOTH CURVE FITTING
       BASED ON LOCAL PROCEDURES", BY HIROSHI AKIMA.


      A DESCRIPTION OF THE ALGORITHM USED PLUS THE ORIGINAL
      FORTRAN PROGRAM IS GIVEN IN THE OCTOBER 1972 ISSUE,
      COMMUNICATIONS OF THE ACM, PAGE 914, ENTITLED:
      "INTERPOLATION AND SMOOTH CURVE FITTING BASED ON LOCAL
       PROCEDURES", BY HIROSHI AKIMA.


.......................................................................



      SUBROUTINE  INTRPL(L,X,Y,N,U,V)
  INTERPOLATION OF A SINGLE-VALUED FUNCTION
  THIS SUBROUTINE INTERPOLATES, FROM VALUES OF THE FUNCTION
  GIVEN AS ORDINATES OF INPUT DATA POINTS IN AN X-Y PLANE
  AND FOR A GIVEN SET OF X VALUES (ABSCISSAS), THE VALUES OF
  A SINGLE-VALUED FUNCTION Y = Y(X).
  THE INPUT PARAMETERS ARE
      L  = NUMBER OF INPUT DATA POINTS
           (MUST BE 2 OR GREATER)
      X  = ARRAY OF DIMENSION L STORING THE X VALUES
           (ABSCISSAS) OF INPUT DATA POINTS
           (IN ASCENDING ORDER)
      Y  = ARRAY OF DIMENSION L STORING THE Y VALUES
           (ORDINATES) OF INPUT DATA POINTS
      N  = NUMBER OF POINTS AT WHICH INTERPOLATION OF THE
           Y VALUE (ORDINATE) IS DESIRED
           (MUST BE 1 OR GREATER)
      U  = ARRAY OF DIMENSION N STORING THE X VALUES
```

```
C           (ABSCISSAS) OF DESIRED POINTS
C     THE OUTPUT PARAMETER IS
C         V  = ARRAY OF DIMENSION N WHERE THE INTERPOLATED Y
C              VALUES (ORDINATES) ARE TO BE DISPLAYED
C     DECLARATION STATEMENTS
      DIMENSION    X(L),Y(L),U(N),V(N)
      EQUIVALENCE  (P0,X3),(Q0,Y3),(Q1,T3)
      REAL         M1,M2,M3,M4,M5
      EQUIVALENCE  (UK,DX),(IMN,X2,A1,M1),(IMX,X5,A5,M5),
     1             (J,SW,SA),(Y2,W2,W4,Q2),(Y5,W3,Q3)
C     PRELIMINARY PROCESSING
   10 L0=L
      LM1=L0-1
      LM2=LM1-1
      LP1=L0+1
      N0=N
      IF(LM2.LT.0)          GO TO 90
      IF(N0.LE.0)           GO TO 91
      DO 11  I=2,L0
        IF(X(I-1)-X(I))     11,95,96
   11   CONTINUE
      IPV=0
C     MAIN DO-LOOP
      DO 80  K=1,N0
        UK=U(K)
C     ROUTINE TO LOCATE THE DESIRED POINT
   20   IF(LM2.EQ.0)        GO TO 27
        IF(UK.GE.X(L0))     GO TO 26
        IF(UK.LT.X(1))      GO TO 25
        IMN=2
        IMX=L0
   21   I=(IMN+IMX)/2
        IF(UK.GE.X(I))      GO TO 23
   22   IMX=I
        GO TO 24
   23   IMN=I+1
   24   IF(IMX.GT.IMN)      GO TO 21
        I=IMX
        GO TO 30
   25   I=1
        GO TO 30
   26   I=LP1
        GO TO 30
   27   I=2
C     CHECK IF I = IPV
   30   IF(I.EQ.IPV)        GO TO 70
        IPV=I
C     ROUTINES TO PICK UP NECESSARY X AND Y VALUES AND
```

```
C        TO ESTIMATE THEM IF NECESSARY                                  INTR1970
   40 J=I                                                               INTR1980
      IF(J.EQ.1)         J=2                                            INTR1990
      IF(J.EQ.LP1)       J=L0                                           INTR2000
      X3=X(J-1)                                                         INTR2010
      Y3=Y(J-1)                                                         INTR2020
      X4=X(J)                                                           INTR2030
      Y4=Y(J)                                                           INTR2040
      A3=X4-X3                                                          INTR2050
      M3=(Y4-Y3)/A3                                                     INTR2060
      IF(LM2.EQ.0)       GO TO 43                                       INTR2070
      IF(J.EQ.2)         GO TO 41                                       INTR2080
      X2=X(J-2)                                                         INTR2090
      Y2=Y(J-2)                                                         INTR2100
      A2=X3-X2                                                          INTR2110
      M2=(Y3-Y2)/A2                                                     INTR2120
      IF(J.EQ.L0)        GO TO 42                                       INTR2130
   41 X5=X(J+1)                                                         INTR2140
      Y5=Y(J+1)                                                         INTR2150
      A4=X5-X4                                                          INTR2160
      M4=(Y5-Y4)/A4                                                     INTR2170
      IF(J.EQ.2)         M2=M3+M3-M4                                    INTR2180
      GO TO 45                                                          INTR2190
   42 M4=M3+M3-M2                                                       INTR2200
      GO TO 45                                                          INTR2210
   43 M2=M3                                                             INTR2220
      M4=M3                                                             INTR2230
   45 IF(J.LE.3)         GO TO 46                                       INTR2240
      A1=X2-X(J-3)                                                      INTR2250
      M1=(Y2-Y(J-3))/A1                                                 INTR2260
      GO TO 47                                                          INTR2270
   46 M1=M2+M2-M3                                                       INTR2280
   47 IF(J.GE.LM1)       GO TO 48                                       INTR2290
      A5=X(J+2)-X5                                                      INTR2300
      M5=(Y(J+2)-Y5)/A5                                                 INTR2310
      GO TO 50                                                          INTR2320
   48 M5=M4+M4-M3                                                       INTR2330
C NUMERICAL DIFFERENTIATION                                             INTR2340
   50 IF(I.EQ.LP1)       GO TO 52                                       INTR2350
      W2=ABS(M4-M3)                                                     INTR2360
      W3=ABS(M2-M1)                                                     INTR2370
      SW=W2+W3                                                          INTR2380
      IF(SW.NE.0.0)      GO TO 51                                       INTR2390
      W2=0.5                                                            INTR2400
      W3=0.5                                                            INTR2410
      SW=1.0                                                            INTR2420
   51 T3=(W2*M2+W3*M3)/SW                                               INTR2430
      IF(I.EQ.1)         GO TO 54                                       INTR2440
```

```
 52    W3=ABS(M5-M4)
       W4=ABS(M3-M2)
       SW=W3+W4
       IF(SW.NE.0.0)      GO TO 53
       W3=0.5
       W4=0.5
       SW=1.0
 53    T4=(W3*M3+W4*M4)/SW
       IF(I.NE.LP1)       GO TO 60
       T3=T4
       SA=A2+A3
       T4=0.5*(M4+M5-A2*(A2-A3)*(M2-M3)/(SA*SA))
       X3=X4
       Y3=Y4
       A3=A2
       M3=M4
       GO TO 60
 54    T4=T3
       SA=A3+A4
       T3=0.5*(M1+M2-A4*(A3-A4)*(M3-M4)/(SA*SA))
       X3=X3-A4
       Y3=Y3-M2*A4
       A3=A4
       M3=M2
C DETERMINATION OF THE COEFFICIENTS
 60    Q2=(2.0*(M3-T3)+M3-T4)/A3
       Q3=(-M3-M3+T3+T4)/(A3*A3)
C COMPUTATION OF THE POLYNOMIAL
 70    DX=UK-P0
 80    V(K)=Q0+DX*(Q1+DX*(Q2+DX*Q3))
      RETURN
C ERROR EXIT
 90   WRITE (6,2090)
      GC TO 99
 91   WRITE (6,2091)
      GC TO 99
 95   WRITE (6,2095)
      GO TO 97
 96   WRITE (6,2096)
 97   WRITE (6,2097)    I,X(I)
 99   WRITE (6,2099)    L0,N0
      RETURN
C FORMAT STATEMENTS
2090  FCRMAT(1X/22H  ***   L = 1 OR LESS./)
2091  FCRMAT(1X/22H  ***   N = 0 OR LESS./)
2095  FCRMAT(1X/27H  ***   IDENTICAL X VALUES./)
2096  FORMAT(1X/33H  ***   X VALUES OUT OF SEQUENCE./)
2097  FCRMAT(6H    I =,I7,10X,6HX(I) =,E12.3)
```

```
2099 FORMAT(6H   L =,I7,10X,3HN =,I7/                                    INTR2930
    1       36H ERROR DETECTED IN ROUTINE     INTRPL)                      INTR2940
      END                                                                 INTR2950
```

****
****
END OF THESIS
****
****

LIST OF REFERENCES

1. Heflinger, H. O., Wuerker, R. F., and Brooks, R. E., "Holographic Interferometry," Journal of Applied Physics, v. 37, No. 2, p. 642-649, February 1966.

2. Collier, R. J., Burckhardt, C. B., and Lin, L. H., Optical Holography, Academic Press, 1971.

3. Matulka, R. D., and Collins, D. J., "Determination of Three-Dimensional Refractive Index Fields by Holographic Interferometry," Journal of Applied Physics, v. 42, p. 1109-1119, 1 March 1971.

4. Collins, D. J. and Kosakoski, R. A., Application of Holographic Interferometry to Density Field Determination in Transonic Corner Flow, Aeronautical Engineer Thesis, Naval Postgraduate School, December, 1972.

5. Jagota, R. C. and Collins, D. J., "Finite Fringe Holographic Interferometry Applied to a Right Circular Cone at Angle of Attack," Journal of Applied Mechanics, December, 1972.

6. Naval Electronics Laboratory Center Technical Document 47, Holography Manual, by P. G. Lingenfelder, January, 1969.

7. Optics Technology, Inc. Educational Series No. 1, Experiments in Physical Optics Using Continuous Laser Light, by T. J. Perkins, 1964.

8. Matulka, R. D., The Application of Holographic Interferometry to the Determination of Asymmetric Three-Dimensional Density Fields in Free-Jet Flow, Ph.D. Thesis, Naval Postgraduate School, June 1970.

9. Jones, D. J., "Tables of Inviscid Supersonic Flow About Circular Cones at Incidence, Parts I and II," Advisory Group for Aero-Space Research and Development, November, 1969.

10. Van Houten, P. E., The Application of Holographic Interferometry to the Determination of Discontinuous Three-Dimensional Density Fields, Aeronautical Engineer Thesis, Naval Postgraduate School, December, 1972. (V168)

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
2.	Library, Code 0212 Naval Postgraduate School Monterey, California 93940	2
3.	Professor R. W. Bell, Code 57Be Department of Aeronautics Naval Postgraduate School Monterey, California	1
4.	Professor D. J. Collins, Code 57Co Department of Aeronautics Naval Postgraduate School Monterey, California 93940	1
5.	LT Richard Allan Everett 2714 Penrose Street San Diego, California	1

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

ORIGINATING ACTIVITY (Corporate author) Naval Postgraduate School Monterey, California 93940	2a. REPORT SECURITY CLASSIFICATION Unclassified 2b. GROUP

REPORT TITLE

Experimental Techniques in Holographic Interferometry

DESCRIPTIVE NOTES (Type of report and, inclusive dates)

Master's Thesis, June 1973

AUTHOR(S) (First name, middle initial, last name)

Richard Allan Everett

REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
June 1973	92	10

a. CONTRACT OR GRANT NO. b. PROJECT NO. c. d.	9a. ORIGINATOR'S REPORT NUMBER(S) 9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

0. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

1. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY Naval Postgraduate School Monterey, California 93940

3. ABSTRACT

Fiber light guides are used in conjunction with holographic interferometry. A Michelson interferometer was constructed to test for temporal coherence of light passing through fiber optics. A finite-fringe hologram of a no-flow condition was taken to prove the feasibility of applying fiber optics to this field of flow investigation.

The effect of opaque bodies on interferometric data inversion was sought. Two schemes for replacing the missing fringe data were used to see if the accuracy of the calculated density fields could be enhanced.

KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Holographic Interferometry						

DD FORM 1 NOV 65 1473 (BACK)
S/N 0101-807-6821

A-31409

Thesis 145304
E783 Everett
c.1 Experimental techniques in holographic interferometry.